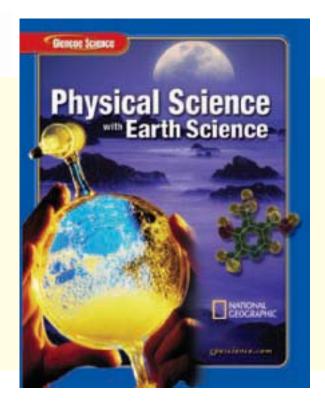




### Glencoe Science

# Physical Science with Earth Science

Moonrise over a rocky Pacific coast serves as the background for a color-enhanced image that shows the emulsifying property of a detergent and a computergenerated model of the chemical structure of vitamin B<sub>6</sub>.





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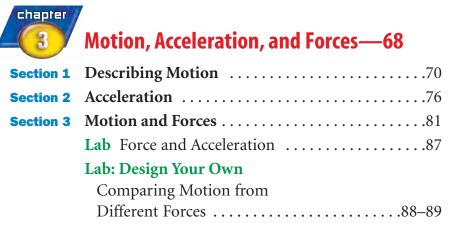
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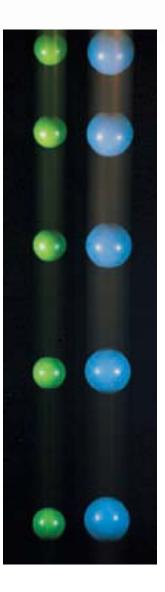


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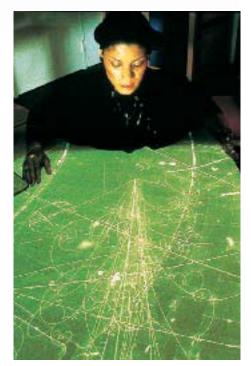
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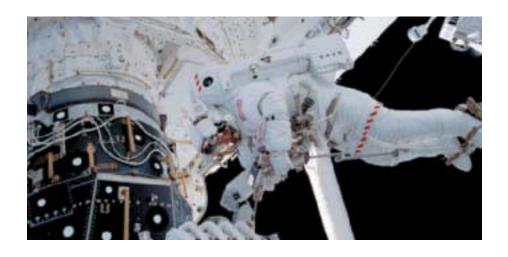
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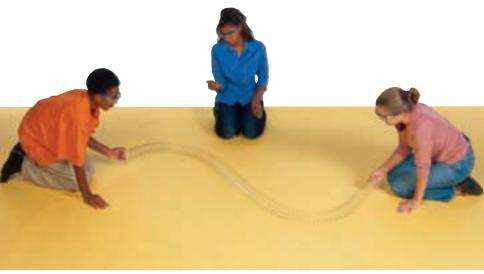
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790, 818

**Language Arts:** 132, 154, 232, 615, 837

**Life Science:** 54, 341, 342, 428, 522, 586, 695, 735, 768, 774, 827

**Physics:** 30, 90, 188, 220, 346, 358, 416, 525, 673

**Social Studies:** 297, 497, 799





5, 7, 12, 18, 37, 45, 50, 69, 72, 75, 82, 97, 101, 105, 127, 130, 141, 153, 163, 172, 185, 187, 204, 217, 227, 234, 253, 256, 261, 274, 287, 293, 305, 319, 325, 340, 353, 359, 374, 376, 391, 396, 412, 423, 437, 442, 455, 473, 474, 485, 498, 505, 517, 528, 530, 551, 557, 566, 577, 579, 591, 593, 595, 607, 614, 622, 632, 645, 657, 658, 667, 687, 691, 719, 722, 727, 751, 762, 770, 785, 790, 803, 817, 821, 834

### **Standardized Test Practice**

34–35, 64–65, 94–95, 124–125, 150–151, 182–183, 214–215, 248–249, 284–285, 316–317, 350–351, 386–387, 420–421, 452–453, 482–483, 514–515, 546–547, 574–575, 604–605, 642–643, 682–683, 716–717, 748–749, 782–783, 814–815, 846–847



# Science and Technology

# How Are Billiards & Bottles Connected?



### chapter



### BIG (Idea

Science is a method of learning and communicating information about the natural world.

# 1.1 The Methods of Science

MAIN (Idea Scientific investigations don't always proceed with identical steps but do contain similar methods.

# 1.2 Standards of Measurement

MAIN (Idea Standard measurement units, such as centimeters and seconds, are exact quantities used to compare measurements.

# 1.3 Communicating with Graphs

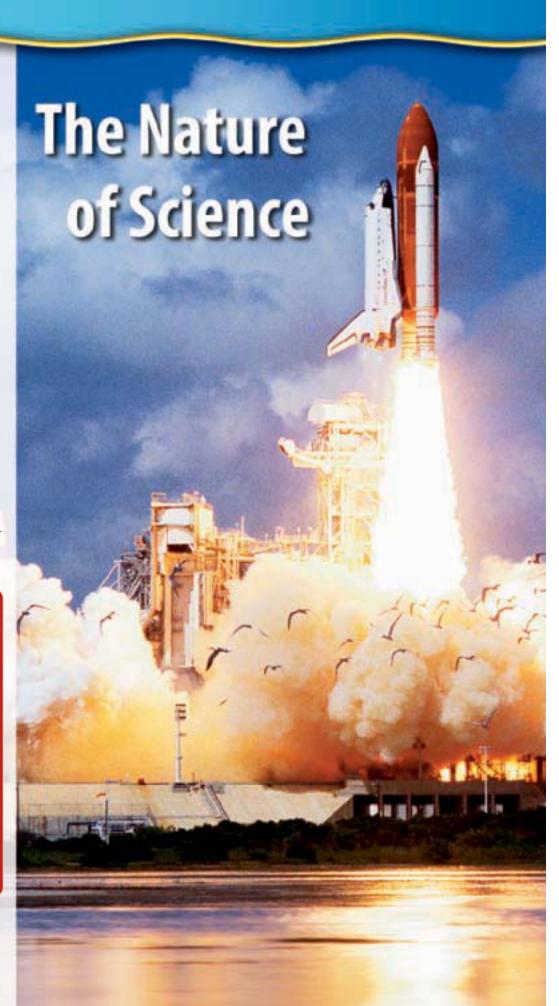
MAIN (Idea Graphs are a visual representation of numerical data.

### Out of This World

The space program was developed in response to many unanswered questions. Scientists have worked together to develop ways in which to answer those questions. In this chapter, you will learn how scientists learn about the natural world.

### **Science Journal**

Look at the picture above. Write in your Science Journal why scientists study space.



### **Start-Up Activities**



### **Understanding Measurements**

Before there were measurement standards, people used parts of the body for measuring items. The length from the tip of the elbow to the end of the middle finger was a *cubit*. The *foot* was the length of a man's foot and was used to measure distance. How does the length of your classroom differ when measured using several students' feet?



- 1. Complete the safety form.
- 2. Estimate the distance in feet across the classroom. Record this number in your Science Journal.
- 3. Walk across your classroom by placing the heel of one foot against the toes of your other foot. Count and record the number of steps in your Science Journal.
- 4. Measure the lengths of your two feet and average them. Calculate the distance of the classroom by multiplying the average length of your feet by the number of
- 5. Measure the distance across the classroom using a tape measure.
- **6. Think Critically** Compare the distance across the classroom using your foot with the distance using other classmates' feet. How does your calculated measurement compare to your classmates' calculated measurements?



**Scientific Processes** Make the following Foldable to help identify what you already

know, what you want to know, and what you learned about science.

STEP 1 Fold a sheet of paper vertically from side to side. Make the front edge about 1.25 cm shorter than the back edge.



STEP 2 Turn lengthwise and fold into thirds.



STEP 3 **Unfold and cut** only the top layer along both folds to make three tabs. Label each tab.



**Identify Questions** Before you read the chapter, write what you already know about science under the left tab of your Foldable, and write questions about what you'd like to know under the center tab. After you read the chapter, list what you learned under the right tab.



Preview this chapter's content and activities at gpescience.com

# The Methods of Science

### **Reading Guide**

### **What** You'll Learn

- Identify the steps scientists often use to solve problems.
- Describe why scientists use variables.
- Compare and contrast science and technology.

### Why It's Important

Using scientific methods will help you solve problems.

### Review Vocabulary

**investigation:** to observe or study by close examination

### **New Vocabulary**

- scientific method
- hypothesis
- experiment
- variable
- dependent variable
- independent variable
- constant
- control
- bias
- model
- theory
- scientific law
- technology

### What is science?

Science is not just a subject in school. It is a method for studying the natural world. After all, science comes from the Latin word *scientia*, which means "knowledge." Science is a process that uses observation and investigation to gain knowledge about events in nature.

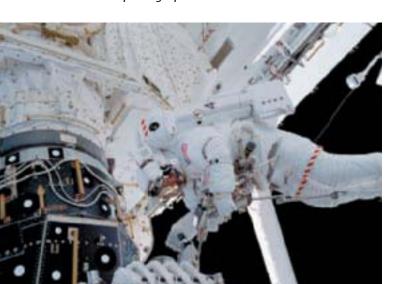
Nature follows a set of rules. Many rules, such as those concerning how the human body works, are complex. Other rules, such as the fact that Earth rotates about once every 24 h, are much simpler. Scientists ask questions to learn about the natural world.

**Major Categories of Science** Science covers many different topics that can be classified according to three main categories. (1) Life science deals with living things. (2) Earth science investigates Earth and space. (3) Physical science deals with matter and

energy. In this textbook, you will study mainly physical science. Sometimes, though, a scientific study will overlap the categories. One scientist, for example, might study the motions of the human body to understand how to build better artificial limbs. Is this scientist studying energy and matter or how muscles operate? She is studying both life science and physical science. It is not always clear what kind of science you are using, as shown in **Figure 1.** 

**Figure 1** Astronaut Michael Lopez-Alegria uses a pistol-grip tool on the *International Space Station*.

**Observe** What evidence do you see of the three main branches of science in the photograph?



Science Explains Nature Scientific explanations help you understand the natural world. Sometimes these explanations must be modified. As more is learned about the natural world, some of the earlier explanations might be found to be incomplete or new technology might provide more accurate answers.

For example, look at **Figure 2.** In the late eighteenth century, most scientists thought that heat was an invisible fluid with no mass. Scientists observed that heat seems to flow like a fluid. It also moves away from a warm body in all directions, just as a fluid moves outward when you spill it on the floor.

However, the heat fluid idea did not explain everything. If heat was an actual fluid, an iron bar at a temperature of 1,000°C should have more mass than it does at 100°C because it would have more of the heat fluid in it. Eighteenth-century scientists thought they were not able to measure the small mass of the heat fluid on the balances they had. When additional investigations showed no difference in mass, scientists had to change the explanation.

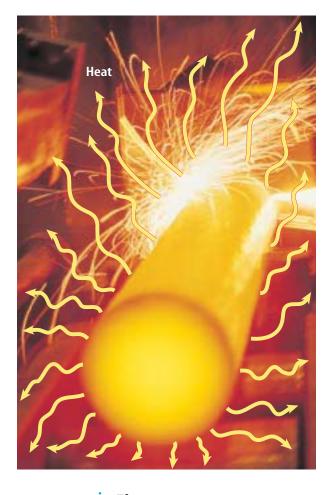


Figure 2 Many years ago, scientists thought that heat, such as in this metal rod, was a fluid. **Infer** how heat acts like a fluid.

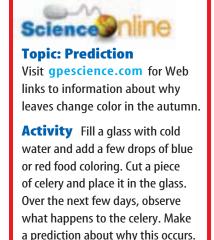
**Investigations** Scientists learn new information about the natural world by performing investigations, which can be done many different ways. Some investigations involve simply observing something that occurs and recording the observations, such as in a journal. Other investigations involve setting up experiments that test the effect of one thing on another. Some investigations involve building a model that resembles something in the natural world and then testing the model to see how it acts. Often, a scientist will use something from all three types of investigations when attempting to learn about the natural world.



Reading Check Why do scientific explanations change?

### **Scientific Methods**

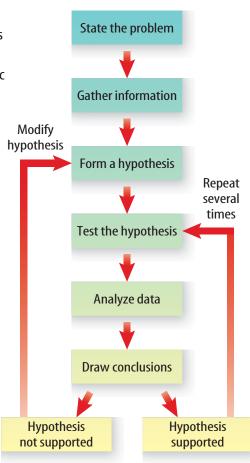
Although scientists do not always follow a rigid set of steps, investigations often follow a general pattern. An organized set of investigation procedures is called a scientific method. Six common steps found in scientific methods are shown in **Figure 3.** A scientist might add new steps, repeat some steps many times, or skip steps altogether when doing an investigation.



Support your answer with evidence.

**Figure 3** The series of procedures shown here is one way to use scientific methods to solve a problem.

**Explain** what should be done if your hypothesis is not supported.



**Stating a Problem** Many scientific investigations begin when someone observes an event in nature and wonders why or how it occurs. Then the question of "why" or "how" is the problem. Sometimes a statement of a problem arises from an activity that is not working. Some early work on guided missiles showed that the instruments in the nose of the missiles did not always work. The problem statement involved finding a material to protect the instruments from the harsh conditions of flight.

Later, National Aeronautics and Space Administration (NASA) scientists made a similar problem statement. They wanted to build a new vehicle—the space shuttle—that could carry people to outer space and back again. Guided missiles did not have this capability. NASA needed to find a material for the outer surface of the space shuttle that could withstand the heat and forces of re-entry into Earth's atmosphere.

Researching and Gathering Information Before testing a hypothesis, it is useful to learn as much as possible about the background of the problem. Have others found information that will help determine what tests to do and what tests will not be helpful? The NASA scientists gathered information about melting points and other properties of the various materials that might be used. In many cases, tests had to be performed to learn the properties of new, recently created materials.

**Forming a Hypothesis** A **hypothesis** is a possible explanation for a problem using what you know and what you observe. NASA scientists knew that a ceramic coating had been found to solve the guided missile problem. They hypothesized that a ceramic material also might work on the space shuttle.

**Testing a Hypothesis** Some hypotheses can be tested by making observations. Others can be tested by building a model and relating it to real-life situations. One common way to test a hypothesis is to perform an experiment. An **experiment** tests the effect of one thing on another using controlled conditions.

**Variables** An experiment usually contains at least two variables. A **variable** is a factor that can cause a change in the results of an experiment. You might set up an experiment to determine the amount of fertilizer that will help plants grow the biggest. Before you begin your tests, you would need to think of all the factors that might cause the plants to grow bigger. Possible factors include plant type, amount of sunlight, amount of water, room temperature, type of soil, and type of fertilizer.

In this experiment, the amount of growth is the **dependent** variable because its value changes according to the changes in the other variables. The variable you change to see how it will affect the dependent variable is called the independent variable.

**Constants and Controls** To be sure you are testing to see how fertilizer affects growth, you must keep the other possible factors the same. A factor that does not change when other variables change is called a **constant**. You might set up one trial, using the same soil and type of plant. Each plant is given the same amount of sunlight and water and is kept at the same temperature. These are constants. Three of the plants receive a different amount of fertilizer, which is the independent variable.

The fourth plant is not fertilized. This plant is a control. A **control** is the standard by which the test results can be compared. Suppose after several days, the three fertilized plants grow between 2 and 3 cm. If the unfertilized plant grows 1.5 cm, you might infer that the growth of the fertilized plants was due to the fertilizers.

How might the NASA scientists set up an experiment to solve the problem of the damaged tiles shown in **Figure 4?** What are possible variables, constants, and controls?

Reading Check Why is a control used in an experiment?





Through observations of living organisms, Aristotle designed a classification system. Systems used today group organisms according to variables such as habits and physical and chemical features. Research to learn recent reclassifications of organisms. Share your findings with your class.

Figure 4 NASA has had an ongoing mission to improve the space shuttle. A technician is replacing tiles damaged upon re-entry into Earth's atmosphere.



**Figure 5** An exciting and important part of investigating something is sharing your ideas with others, as this student is doing at a science fair. **Identify** possible methods of how scientists can share their research data.

**Analyzing the Data** An important part of every experiment includes recording observations and organizing the test data into easy-toread tables and graphs. Later in this chapter you will study ways to display data. When you are making and recording observations, you should include all results, even unexpected ones. Many important discoveries have been made from unexpected occurrences.

Interpreting the data and analyzing the observations is an important step. If the data are not organized in a logical manner, wrong conclusions can be drawn. No matter how well a scientist communicates and shares that

data, someone else might not agree with the data. Scientists share their data through reports and conferences. In Figure 5, a student is displaying her data.

**Drawing Conclusions** Based on the analysis of your data, you decide whether or not your hypothesis is supported. When lives are at stake, such as with the space shuttle, you must be very sure of your results. For the hypothesis to be considered valid and widely accepted, the experiment must result in the exact same data every time it is repeated. If your experiment does not support your hypothesis, you must reconsider the hypothesis. Perhaps it needs to be revised or your experiment needs to be conducted differently.

**Being Objective** Scientists also should be careful to reduce bias in their experiments. A bias occurs when what the scientist expects changes how the results are viewed. This expectation might cause a scientist to select a result from one trial over those from other trials. Bias also might be found if the advantages of a product being tested are used in a promotion and the drawbacks are not presented.

Scientists can lessen bias by running as many trials as possible and by keeping accurate notes of each observation made. Valid experiments also must have data that are measurable. For example, a scientist performing a global warming study must base his or her data on accurate measures of global temperature. This allows others to compare the results to data they obtain from a similar experiment. Most importantly, the experiment must be repeatable. Findings are supportable when other scientists perform the same experiment and get the same results.



### **Visualizing with Models**

Sometimes, scientists cannot see everything that they are testing. They might be observing something that is too large, too small, or takes too much time to see completely. In these cases, scientists use models. A **model** represents an idea, event, or object to help people better understand it.

**Models in History** Models have been used throughout history. One scientist, Lord Kelvin, who lived in England in the 1800s, was famous for making models. To model his idea of how light moves through space, he put balls into a bowl of jelly and encouraged people to move the balls around with their hands. Kelvin's work to explain the nature of temperature and heat still is used today.

**High-Tech Models** Scientific models don't always have to be something you can touch. Today, many scientists use computers to build models. NASA experiments involving space flight would not be practical without computers. The complex equations would take far too long to calculate by hand, and errors could be introduced much too easily.

Another type of model is a simulator, like the one shown in **Figure 6.** An airplane simulator enables pilots to practice problem solving with various situations and conditions they might encounter when in the air. This model will react the way a plane does when it flies. It gives pilots a safe way to test different reactions and to practice certain procedures before they fly a real plane.



### **Computer Models**

Meteorology has changed greatly due to computer modeling. Using special computer programs, meteorologists now are able to more accurately predict disastrous weather. In your Science Journal, describe how computer models might help save lives.

**Figure 6** Pilots and astronauts use flight simulators for training. **Explain** how these models differ from actual airplanes and spacecraft.





### **Topic: Archimedes' Principle**

Visit **gpescience.com** for Web links to information about Archimedes' principle.

**Activity** Place a full soft-drink bottle, water bottle, or container of milk in a tub of water. What happens to the pop bottle or milk container? Would you classify Archimedes' principle as a scientific theory or scientific law?

Figure 7 Science can't answer all questions.

**Analyze** *Can anyone prove that* you like artwork? Explain.

### **Scientific Theories and Laws**

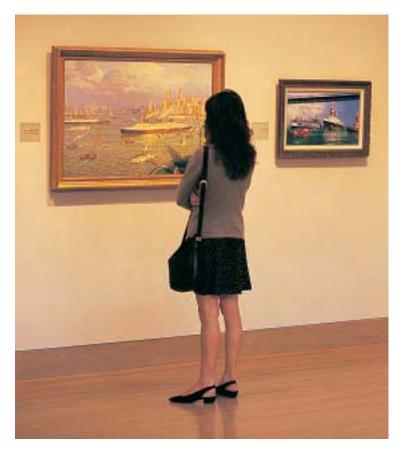
A scientific theory is an explanation of things or events based on knowledge gained from many observations and investigations. It is not a guess. If scientists repeat an investigation and the results always support the hypothesis, the hypothesis can be called a theory. Just because a scientific theory has data supporting it does not mean it will never change. Recall that the theory about heat being a fluid was discarded after further experiments. As new information becomes available, theories can be modified. A theory accepted today might at some time in the future also be discarded.

A scientific law is a statement about what happens in nature and that seems to be true all the time. Laws tell you what will happen under certain conditions, but they don't explain why or how something happens. Gravity is an example of a scientific law. The law of gravity says that any one mass will attract another mass. To date, no experiments have been performed that disprove the law of gravity.

A theory can be used to explain a law. For example, many theories have been proposed to explain how the law of gravity works. Even so, there are few theories in science and even fewer laws.



What is the difference between a scientific theory and a scientific law?



### The Limitations of **Science**

Science can help you explain many things about the world, but science cannot explain or solve everything. Although it's the scientist's job to make hypotheses, the scientist also has to make sure his or her hypotheses can be tested and verified. How do you prove that people will like a play or a piece of music? You cannot and science cannot.

Most questions about emotions and values are not scientific questions. They cannot be tested. You might take a survey to get people's opinions about such questions, but that would not prove that the opinions are true for everyone. A survey might predict that you will like the art in Figure 7, but science cannot prove that you or others will.

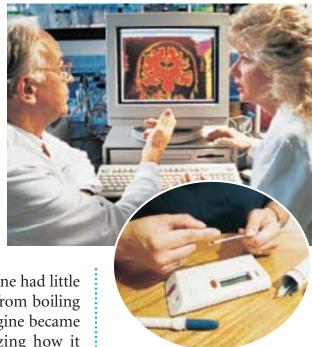
### **Using Science—Technology**

Many people use the terms *science* and *technology* interchangeably, but they are not the same. **Technology** is the application of science to help people. For example, when a chemist develops a new, lightweight material that can withstand great amounts of heat, science is used. When that material is used on the space shuttle, technology is applied. **Figure 8** shows other examples of technology.

Technology doesn't always follow science, however. Sometimes the process of discovery can be reversed. One important historic example of science following technology is the development

of the steam engine. The inventors of the steam engine had little idea of how it worked. They just knew that steam from boiling water could move the engine. Because the steam engine became so important to industry, scientists began analyzing how it worked. Lord Kelvin, James Prescott Joule, and Sadi Carnot, who lived in the 1800s, learned so much from the steam engine that they developed revolutionary ideas about the nature of heat.

Science and technology do not always produce positive results. The benefits of some technological advances, such as nuclear technology and genetic engineering, are subjects of debate. Being more knowledgeable about science can help society address these issues as they arise.



**Figure 8** Technology is the application of science. **Identify** the type of science (life, Earth, or physical) that is applied in these examples of technology.

### section

# 1 review

### Summary

### What is science?

 Scientists ask questions and perform investigations to learn more about the natural world.

### **Scientific Methods**

 Scientists perform the six-step scientific method to test their hypotheses.

### **Visualizing with Models**

Models help scientists visualize concepts.

### **Scientific Theories and Laws**

 A theory is a possible explanation for observations, while a scientific law describes a pattern but does not explain why things happen.

### **Using Science—Technology**

 Technology is the application of science in our everyday lives.

### **Self Check**

- Define the first step a scientist usually takes to solve a problem.
- 2. Explain why a control is needed in a valid experiment.
- **3. Think Critically** What is the dependent variable in an experiment that shows how the volume of gas changes with changes in temperature?

### **Applying Math**

4. Find the Average You perform an experiment to determine how many breaths a fish takes per minute. Your experiment yields the following data: minute 1: 65 breaths; minute 2: 73 breaths; minute 3: 67 breaths; minute 4: 71 breaths; minute 5: 62 breaths. Calculate the average number of breaths that the fish takes per minute.

# Standards of Measurement

#### **Reading Guide**

#### What You'll Learn

- Name the prefixes used in SI and indicate what multiple of ten each one represents.
- Identify SI units and symbols for length, volume, mass, density, time, and temperature.
- Convert related SI units.

#### Why It's Important

By using uniform standards, nations can exchange goods and compare information easily.

#### Review Vocabulary

**measurement:** the dimensions, capacity, or amount of something

#### **New Vocabulary**

- precision
- accuracy
- volume
- mass
- density

**Figure 9** Hands are a convenient measuring tool, but using them can lead to misunderstanding.



#### **Units and Standards**

A standard is an exact quantity that people agree to use to compare measurements. Look at **Figure 9.** Suppose you and a friend want to make some measurements to find out whether a desk will fit through a doorway. You have no ruler, so you decide to use your hands as measuring tools. Using the width of his hands, your friend measures the doorway and says it is 8 hands wide. Using the width of your hands, you measure the desk and find it is  $7\frac{3}{4}$  hands wide. Will the desk fit through the doorway? You can't be sure. What went wrong? Even though you both used hands to measure, you didn't check to see whether your hands were the same width as your friend's.

#### **Precision and Accuracy**

You are watching an archery event. The first person shoots five bull's-eyes in a row. The second person does not hit the bull's-eye at all, but the arrows all are in a similar location. What can be said about these two participants? The first person's aim was both precise and accurate. The second person's aim was only precise. Precision describes how closely measurements are to each other and how carefully measurements were made. Accuracy compares a measurement to the real or accepted value. When taking measurements, it is important to be precise and accurate.

#### **International System of Units**

In 1960, an improved version of the metric system was devised. Known as the International System of Units, this system is often abbreviated SI, from the French *Le Systeme Internationale d'Unites*. SI is an improved, accepted version of the metric system that is based on multiples of ten. It is understood by scientists throughout the world. The standard kilogram, which is kept in Sèvres, France, is shown in **Figure 10.** All kilograms used throughout the world must be exactly the same as the kilogram kept in France.

Each type of SI measurement has a base unit. The meter is the base unit of length. Every type of quantity measured in SI has a symbol for that unit. These names and symbols for the seven base units are shown in **Table 1.** All other SI units are obtained from these seven units.



**SI Prefixes** The SI system is easy to use because it is based on multiples of ten. Prefixes are used with the names of the units to indicate what multiple of ten should be used with the units. For example, the prefix *kilo*- means "1,000." This means that one kilometer equals 1,000 meters. Likewise, one kilogram equals 1,000 grams. Because *deci*- means "one-tenth," one decimeter equals one-tenth of a meter. A decigram equals one-tenth of a gram. The most frequently used prefixes are shown in **Table 2.** 

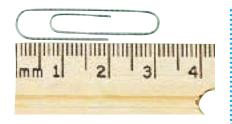
**Figure 10** The standard for mass, the kilogram, and other standards are kept at the International Bureau of Weights and Measures in Sèvres, France. **Explain** the purpose of a standard.



How many meters are in 1 km? How many grams are in 1 dg?

Table 1 SI Base Units		
Quantity Measured	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	S
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Intensity of light	candela	cd

Table 2 Common SI Prefixes		
Prefix	Symbol	Multiplying Factor
Kilo-	k	1,000
Deci-	d	0.1
Centi-	С	0.01
Milli-	m	0.001
Micro-	$\mu$	0.000 001
Nano-	n	0.000 000 001



**Figure 11** One centimeter contains 10 mm.

**Determine** the length of the paper clip in centimeters and in millimeters.

**Converting Between SI Units** Sometimes quantities are measured using different units, as shown in **Figure 11.** A conversion factor is a ratio that is equal to one and is used to change one unit to another. For example, there are 1,000 mL in 1 L, so 1,000 mL = 1 L. If both sides in this equation are divided by l L, the equation becomes:

$$\frac{1,000 \text{ mL}}{1 \text{ L}} = 1$$

To convert units, you multiply by the appropriate conversion factor. For example, to convert 1.255 L to mL, multiply 1.255 L by a conversion factor. Use the conversion factor with new units (mL) in the numerator and the old units (L) in the denominator.

$$1.255 \pm \times \frac{1,000 \text{ mL}}{1 \pm} = 1,255 \text{ mL}$$

#### **Applying Math**

#### **Convert Units**

**CENTIMETERS** How long in centimeters is a 3,075 mm rope?

**IDENTIFY** known values and the unknown value

Identify the known values:

The rope measures 3,075 mm; 1 m = 100 cm = 1,000 mm

Identify the unknown value:

How long is the rope in cm?

SOLVE the problem

This is the equation you need to use:

? cm = 3,075 mm 
$$\times \frac{100 \text{ cm}}{1,000 \text{ mm}}$$

Cancel units and multiply:

$$3,075 \text{ mm} \times \frac{100 \text{ cm}}{1,000 \text{ mm}} = 307.5 \text{ cm}$$

CHECK your answer

Does your answer seem reasonable? Check your answer by multiplying the answer by  $\frac{1,000\,\mathrm{mm}}{100\,\mathrm{cm}}$ . Did you calculate the original length in millimeters?

#### **Practice Problems**

- 1. Your pencil is 11 cm long. How long is it in millimeters?
- **2.** The Bering Land Bridge National Preserve is a summer home to birds. Some birds migrate 20,000 miles. Assume 1 mile equals 1.6 kilometers. Calculate the distance birds fly in kilometers.

For more practice problems, go to page 879 and visit Math Practice at gpescience.com.



**Figure 12** One meter is slightly longer than 1 yard, and 100 m is slightly longer than a football field. **Predict** whether your time for a 100-m dash would be slightly more or less than your time for a 100-yard dash.

Astronomical Units The

Earth to the Sun is called the astronomical unit, AU.

standard measurement

for the distance from

The distance is about 150 billion (1.5  $\times$  10<sup>11</sup>) m.

calculate what 1 AU

In your Science Journal,

would equal in kilometers.

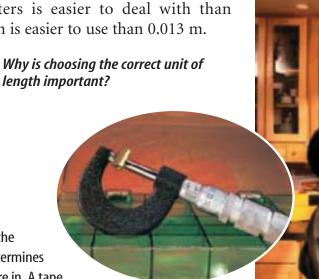
#### **Measuring Distance**

The word *length* is used in many different ways. For example, the length of a novel is the number of pages or words it contains. In scientific measurement, length is the distance between two points. That distance might be the diameter of a hair or the distance from Earth to the Moon. The SI base unit of length is the meter, m. A baseball bat is about 1 m long. Metric rulers and metersticks are used to measure length. Figure 12 compares a meter and a yard.

**Choosing a Unit of Length** As shown in **Figure 13**, the size of the unit you measure with will depend on the size of the object being measured. For example, the diameter of a shirt button is about 1 cm. You probably also would use the centimeter to measure the length of your pencil and the meter to measure the length of your classroom. What unit would you use to measure the distance from your home to school? You probably would want to use a unit larger than a meter. The kilometer, km, which is 1,000 m, is used to measure these kinds of distances.

By choosing an appropriate unit, you avoid large-

digit numbers and numbers with many decimal places. Twenty-one kilometers is easier to deal with than 21,000 m, and 13 mm is easier to use than 0.013 m.



**Figure 13** The size of the object being measured determines which unit you will measure in. A tape measure measures in meters. The micrometer, shown on the left, measures in small lengths. **State** what unit you think it measures.

Reading Check

17



#### Topic: International System of Units

Visit **gpescience.com** for Web links to information about the International System of Units.

**Activity** Measure four different things in your classroom using a different unit—distance, volume, time, or temperature—for each. Use each unit only once. Write the measurements down and using the common prefixes in **Table 2**, convert them to different units.

#### **Measuring Volume**

The amount of space occupied by an object is called its **volume.** If you want to know the volume of a solid rectangle, such as a brick, you measure its length, width, and height and multiply the three numbers and their units together  $(V = l \times w \times h)$ . For a brick, your measurements probably would be in centimeters. The volume would then be expressed in cubic centimeters, cm<sup>3</sup>. To find out how much a moving van can carry, your measurements probably would be in meters, and the volume would be expressed in cubic meters, m<sup>3</sup>, because when you multiply, you add exponents.

**Measuring Liquid Volume** How do you measure the volume of a liquid? A liquid has no sides to measure. In measuring a liquid's volume, you are indicating the capacity of the container that holds that amount of liquid. The most common units for expressing liquid volumes are liters and milliliters. These are measurements used in canned and bottled foods. A liter occupies the same volume as a cubic decimeter, dm<sup>3</sup>. A cubic decimeter is a cube that is 1 dm, or 10 cm, on each side, as in **Figure 14.** 

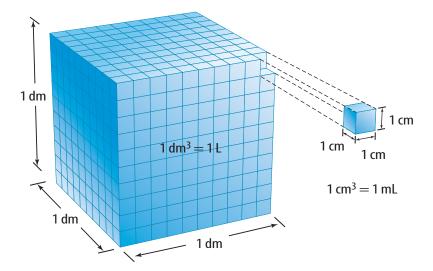
Look at **Figure 14.** One liter is equal to 1,000 mL. A cubic decimeter,  $dm^3$ , is equal to 1,000 cm<sup>3</sup>. Because 1 L = 1 dm<sup>3</sup>, it follows that

$$1 \text{ mL} = 1 \text{ cm}^3$$

Sometimes, liquid volumes such as doses of medicine are expressed in cubic centimeters.

Suppose you wanted to convert a measurement in liters to cubic centimeters. You would use conversion factors to convert L to mL and then mL to cm<sup>3</sup>.

$$1.5 \pm \times \frac{1,000 \text{ mL}}{1 \pm} \times \frac{1 \text{ cm}^3}{1 \text{ mL}} = 1,500 \text{ cm}^3$$



**Figure 14** The large cube has a volume of 1 dm<sup>3</sup>, which is equivalent to 1 L. **Calculate** the cubic centimeters (cm<sup>3</sup>) in the large cube.

Table 3 Densities of Some Materials at 20°C			
Material	Density (g/cm <sup>3</sup> )	Material	Density (g/cm <sup>3</sup> )
Hydrogen	0.000 09	Aluminum	2.7
0xygen	0.001 4	Iron	7.9
Water	1.0	Gold	19.3

#### **Measuring Matter**

A table-tennis ball and a golf ball have about the same volume. But if you pick them up, you will notice a difference. The golf ball has more mass. Mass is a measurement of the quantity of matter in an object. The mass of the golf ball, which is about 45 g, is almost 18 times the mass of the table-tennis ball, which is about 2.5 g. To visualize SI units, see **Figure 15** on the following page.

**Density** A cube of polished aluminum and a cube of silver that are the same size not only look similar but also have the same volume. The mass and volume of an object can be used to find the density of the material the object is made of. **Density** is the mass per unit volume of a material. You find density by dividing an object's mass by the object's volume. For example, the density of an object having a mass of 10 g and a volume of 2 cm<sup>3</sup> is 5 g/cm<sup>3</sup>. **Table 3** lists the densities of some familiar materials.



**Derived Units** The measurement unit for density, g/cm<sup>3</sup>, is a combination of SI units. A unit obtained by combining different SI units is called a derived unit. An SI unit multiplied by itself also is a derived unit. Thus the liter, which is based on the cubic decimeter, is a derived unit. A meter cubed, expressed with an exponent—m<sup>3</sup>—is a derived unit.

#### **Measuring Time and Temperature**

It is often necessary to keep track of how long it takes for something to happen, or whether something heats up or cools down. These measurements involve time and temperature.

Time is the interval between two events. The SI unit for time is the second. In the laboratory, you will use a stopwatch or a clock with a second hand to measure time.



#### **Determining the Density of a Pencil**

#### Procedure Procedure

- **1.** Complete the safety form.
- 2. Find a pencil that will fit in a 100-mL graduated cylinder below the 90-mL mark.
- 3. Measure the mass of the pencil in grams.
- 4. Put 90 mL of water (initial volume) into the 100-mL graduated cylinder. Lower the pencil, eraser first, into the cylinder. Push the pencil down until it is just submerged. Hold it there and record the final volume to the nearest tenth of a milliliter.

#### **Analysis**

- 1. Determine the water displaced by the pencil by subtracting the initial volume from the final volume.
- 2. Calculate the pencil's density by dividing its mass by the volume of water displaced.
- **3.** Is the density of the pencil greater than or less than the density of water? How do you know?

### NATIONAL GEOGRAPHIC VISUALIZING SI DIMENSIONS

#### Figure 15

he characteristics of most of these everyday objects are measured using an international system known as SI dimensions. These dimensions measure length, volume, mass, density, and time. Celsius is not an SI unit but is widely used in scientific work.



**MILLIMETERS** A dime is about 1 mm thick.



METERS A football field is about 91 m long.



**KILOMETERS** The distance from your house to a store can be measured in kilometers.



LITERS This carton holds 1.98 L of frozen yogurt.



MILLILITERS
A teaspoonful
of medicine is
about 5 mL.

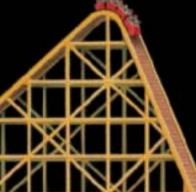


**GRAMS/METER** 

This stone sinks because it is denser—has more grams per cubic meter—than water.



**GRAMS** The mass of a thumbtack and the mass of a textbook can be expressed in grams.



**METERS/SECOND** 

The speed of a roller-coaster car can be measured in meters per second.



CELSIUS Water boils at 100°C and freezes at 0°C.

**What's Hot and What's Not** You will learn the scientific meaning of the word *temperature* in a later chapter. For now, think of temperature as a measure of how hot or how cold something is.

Look at **Figure 16.** For most scientific work, temperature is measured on the Celsius (C) scale. On this scale, the freezing point of water is 0°C, and the boiling point of water is 100°C. Between these points, the scale is divided into 100 equal divisions. Each one represents 1°C. On the Celsius scale, the average human body temperature is 37°C, and a typical room temperature is between 20°C and 25°C.

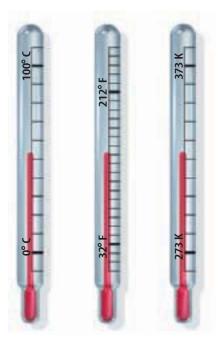
**Kelvin and Fahrenheit** The SI unit of temperature is the kelvin (K). Zero on the Kelvin scale (0 K) is the coldest possible temperature, also known as absolute zero. Absolute zero is equal to -273°C, which is 273° below the freezing point of water.

Most laboratory thermometers are marked only with the Celsius scale. Because the divisions on the two scales are the same size, the Kelvin temperature can be found by adding 273 to the Celsius reading. So, on the Kelvin scale, water freezes at 273 K and boils at 373 K. Notice that degree symbols are not used with the Kelvin scale.

The temperature measurement you are probably most familiar with is the Fahrenheit scale, which was based roughly on the temperature of the human body, 98.6°.



What is the relationship between the Celsius scale and the Kelvin scale?



**Figure 16** These three thermometers illustrate the scales of temperature between the freezing and boiling points of water. **Compare** the boiling points of the three scales.

### section (2) review

#### **Summary**

#### **Precision and Accuracy**

 Precision is the description of how close measurements are to each other.

#### **International System of Units**

- The International System of Units, or SI, was established to provide a standard of measurement and reduce confusion.
- Conversion factors are used to change one unit to another and involve using a ratio equal to 1.

#### Measuring

• The size of an object being measured determines which unit you will measure in.

#### **Self Check**

- Explain why it is important to have exact standards of measurement.
- **2. Explain** why density is a derived unit.
- **3. Think Critically** Using a metric ruler, measure a shoe box and a pad of paper. Find the volume of each in cubic centimeters. Then convert the units to mL.

#### **Applying Math**

- Convert Units Make the following conversions: 27°C to Kelvin, 20 dg to milligrams, and 3 m to decimeters.
- **5. Calculate Density** What is the density of an unknown metal that has a mass of 158 g and a volume of 20 mL? Use **Table 3** to identify this metal.

# **Communicating** with Graphs

#### **Reading Guide**

#### What You'll Learn

- Identify three types of graphs and explain the ways they are
- **Distinguish** between dependent and independent variables.
- **Analyze** data using the various types of graphs.

#### Why It's Important

Graphs are a quick way to communicate a lot of information in a small amount of space.

#### Review Vocabulary

data: information gathered during an investigation or observation

#### **New Vocabulary**

graph

**A Visual Display** 

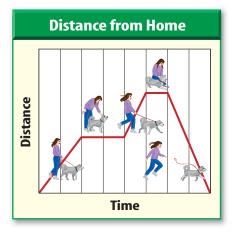
Scientists often graph the results of their experiments because they can detect patterns in the data easier in a graph than in a table. A graph is a visual display of information or data. **Figure 17** is a graph that shows a girl walking her dog. The horizontal axis, or the x-axis, measures time. Time is the independent variable because as it changes, it affects the measure of another variable. The distance from home that the girl and the dog walk is the other variable. It is the dependent variable and is measured on the vertical axis, or  $\nu$ -axis.

Graphs are useful for displaying numerical information in business, science, sports, advertising, and many everyday situations. Different kinds of graphs—line, bar, and circle—are appropriate for displaying different types of information.

Reading Check What are three common types of graphs?

Business people, as well as scientists, need an organized method to display data. Graphs make it easier to understand patterns by displaying data in a visual manner. Scientists often graph their data to detect patterns that would not have been evident in a table. Business people might graph sales dollars to determine trends. Different graphs display information by different methods. The conclusions drawn from graphs must be based on accurate information.

**Figure 17** This graph tells the story of the motion that takes place when a girl takes her dog for an 8-min walk.



#### **Line Graphs**

A line graph can show any relationship where the dependent variable changes due to a change in the independent variable. Line graphs often show how a relationship between variables changes over time. You can use a line graph to track many things, such as how certain stocks perform or how the population changes over any period of time—a month, a week, or a year.

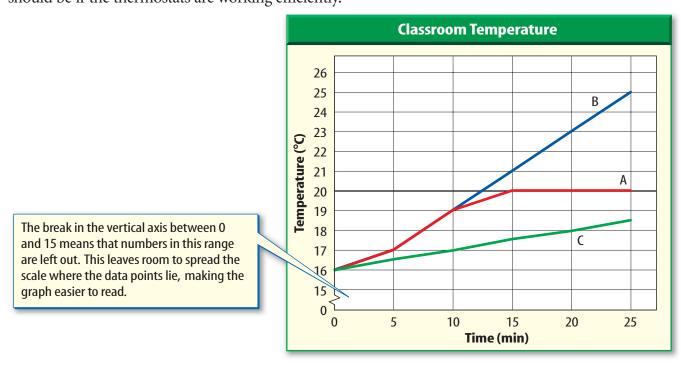
You can show more than one event on the same graph as long as the relationship between the variables is identical. Suppose a builder had three choices of thermostats for a new school. He wanted to test them to know which was the best brand to install throughout the building. He installed a different thermostat in classrooms A, B, and C. He set each thermostat at 20°C. He turned the furnace on and checked the temperatures in the three rooms every 5 min for 25 min. He recorded his data in **Table 4.** 

The builder then plotted the data on a graph. He could see from the table that the data did not vary much for the three classrooms. So he chose small intervals for the y-axis and left part of the scale out (the part between 0° and 15°), as shown in Figure 18. This allowed him to spread out the area on the graph where the data points lie. You easily can see the contrast in the colors of the three lines and their relationship to the black horizontal line. The black line represents the thermostat setting and is the control. The control is what the resulting room temperature of the classrooms should be if the thermostats are working efficiently.

Table 4 Room Temperature			
Time*	Classro A	oom Tempei B	rature (C°) C
0	16	16	16
5	17	17	16.5
10	19	19	17
15	20	21	17.5
20	20	23	18
25	20	25	18.5

<sup>\*</sup>minutes after turning on heat

**Figure 18** The room temperatures of classrooms A, B, and C are shown in contrast to the thermostat setting of 20°C. **Identify** the thermostat that achieved its temperature setting the quickest.





**Figure 19** Graphing calculators are valuable tools for making graphs.

**Constructing Line Graphs** Besides choosing a scale that makes a graph readable, as illustrated in Figure 18, other factors are involved in constructing useful graphs. The most important factor in making a line graph is always using the x-axis for the independent variable. The y-axis always is used for the dependent variable. Because the points in a line graph are related, you connect the points.

Another factor in constructing a graph involves units of measurement. For example, you might use a Celsius thermometer for one part of your experiment and a Fahrenheit thermometer for another. But you must first convert your temperature readings to the same unit of measurement before you make your graph.

In the past, graphs had to be made by hand, with each point plotted individually. Today, scientists use a variety of tools, such as computers and graphing calculators like the one shown in **Figure 19,** to help them draw graphs.

#### **Applying Math**

#### **Make and Use Graphs**

**TEMPERATURE** In an experiment, you checked the air temperature at certain hours of the day. At 8 A.M., the temperature was 27°C; at noon, the temperature was 32°C; and at 4 P.M., the temperature was 30°C. Graph the results of your experiment.

#### IDENTIFY known values

time = independent variable, which is the x-axis

temperature = dependent variable, which is the  $\gamma$ -axis

#### **GRAPH** the problem

Graph time on the x-axis and temperature on the y-axis. Mark the equal increments on the graph to include all measurements. Plot each point on the graph by finding the time on the x-axis and moving up until you find the recorded temperature on the y-axis. Place a point there. Continue placing points on the graph. Then connect the points from left to right.

#### **Practice Problems**

As you train for a marathon, you compare your previous times. In year one, you ran it in 5.2 h; in year two, you ran it in 5 h; in year three, you ran it in 4.8 h; in year four, you ran it in 4.3 h; and in year five, you ran it in 4 h.

- **1.** Make a table of your data.
- 2. Graph the results of your marathon races.
- **3.** Calculate your percentage of improvement from year one to year five.

For more practice problems, go to page 879 and visit Math Practice at gpescience.com.

#### **Bar Graphs**

A bar graph is useful for comparing information collected by counting. For example, suppose you counted the number of students in every classroom in your school on a particular day and organized your data as in **Table 5.** You could show these data in a bar graph like the one shown in **Figure 20.** Uses for bar graphs include comparisons of oil or crop productions, costs, or data in promotional materials. Each bar represents a quantity counted at a particular time, which should be stated on the graph. As on a line graph, the independent variable is plotted on the x-axis and the dependent variable is plotted on the y-axis.

Recall that you might need to place a break in the scale of the graph to better illustrate your results. For example, if your data were 1,002, 1,010, 1,030, and 1,040 and the intervals on the scale were every 100 units, you might not be able to see the difference from one bar to another. If you had a break in the scale and started your data range at 1,000 with intervals of ten units, you could make a more accurate comparison.



Describe possible data where using a bar graph would be better than using a line graph.

Table 5 Classroom Size	
Number of Students	Number of Classrooms
20	1
21	3
22	3
23	2
24	3
25	5
26	5
27	3

**Figure 20** The height of each bar corresponds to the number of classrooms having a particular number of students.



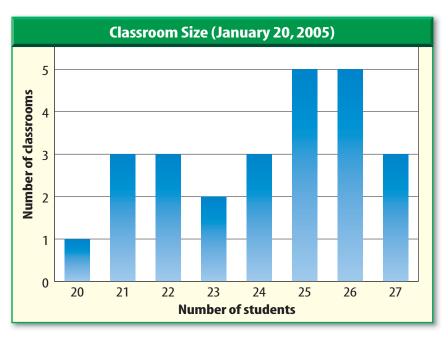
#### **Graphing Temperature Change**

#### 

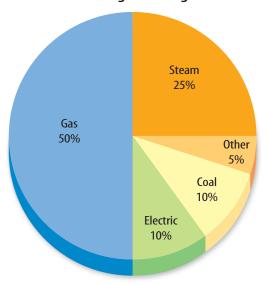
- 1. Complete the safety form.
- 2. Add 1 c of cold water to a medium-sized plastic **bowl.** Add 1/2 c of **ice** and 2 tbs of table salt to the water.
- **3.** Fill a clear-plastic cup 2/3 full with room temperature water. Measure the temperature of the water using a thermometer.
- **4.** Place the plastic cup with the thermometer into the iced water. Make sure the iced water surrounds the water in the cup but does not enter the cup.
- 5. Measure and record the temperature every 30 s for 5 min.

#### **Analysis**

- 1. Identify the dependent and independent variables.
- 2. Make a line graph of the data recorded in step 5.



#### **Heating Fuel Usage**



**Figure 21** A circle graph shows the different parts of a whole quantity.

**Calculate** the angle of gas usage.

#### **Circle Graphs**

A circle graph, or pie graph, is used to show how some fixed quantity is broken down into parts. The circular pie represents the total. The slices represent the parts and usually are represented as percentages of the total.

**Figure 21** illustrates how a circle graph could be used to show the percentage of buildings in a neighborhood using each of a variety of heating fuels. You easily can see that more buildings use gas heat than any other kind of heating fuel system. What else does the graph tell you?

To create a circle graph, you start with the total of what you are analyzing. There are 72 buildings in the neighborhood. For each type of heating fuel, you

divide the number of buildings using each type of fuel by the total (72). You then multiply that decimal by 360° to determine the angle that the decimal makes in the circle. Eighteen buildings use steam. Therefore,  $(18 \div 72) \times 360^{\circ} = 90^{\circ}$  on the circle graph. You then would measure 90° on the circle with your protractor to show 25 percent.

When you use graphs, think carefully about the conclusions you can draw from them. You want to make sure your conclusions are based on accurate information and that you use scales that help make your graph easy to read.

#### section

### геуіеш

#### **Summary**

#### **A Visual Display**

- Graphs are a visual representation of data.
- Scientists often graph their data to detect patterns.
- The type of graph used is based on the conclusions you want to identify.

#### **Line Graphs**

 A line graph shows how a relationship between two variables changes over time.

#### **Bar Graphs**

 Bar graphs are best used to compare information collected by counting.

#### **Circle Graphs**

• A circle graph shows how a fixed quantity is broken down into parts.

#### **Self Check**

- 1. Identify the kind of graph that would best show the results of a survey of 144 people where 75 ride a bus, 45 drive cars, 15 carpool, and 9 walk to work.
- **2. State** which type of variable is plotted on the *x*-axis and which type is plotted on the y-axis.
- **3. Explain** why the points in a line graph are connected.
- 4. Think Critically How are line, bar, and circle graphs similar? How are they different?

#### **Applying Math**

**5. Percentage** In a survey, it was reported that 56 out of 245 people would rather drink orange juice in the morning than coffee. Calculate what percentage of a circle graph this data would occupy.



## What's my groeph?

You have heard that a picture is worth a thousand words. For scientists, it is also true that a graph is worth a thousand numbers. Graphs give us a visual display of data collected during experiments.

#### Real-World Problem

How are line, bar, and circle graphs used for analyzing different kinds of data?

#### Goals

■ **Compare and contrast** the three different types of graphs and how they are used.

#### **Materials**

Science Journal pencil small ruler compass protractor \*circle template

\*Alternate material

#### **Safety Precautions**



#### Procedure

- 1. Complete the safety form.
- **2.** Copy the data tables into your Science Journal. Examine the data listed in the tables.
- **3. Discuss** with other students the type of graph to be used for each data table.
- **4. Graph** the data for each table in your Science Journal.

### Conclude and Apply-

- **1. Explain** why you chose the type of graph you made for each data table.
- **2. Discuss** the advantages of looking at a graph instead of just looking at numbers in a data table.

Data Table 1 Home Energy Use	
Type of Energy Use	Percentage
Heating and Cooling	44%
Water Heating	14%
Refrigerator	9%
Light Cooking and Other	33%

Data Table 2 Motion of an Object	
Time (s)	Distance (m)
0	0
5	3
10	6
15	9

tornadoes by month	
Month	Average # of Tornadoes
March	53
April	107
May	176
June	168
July	94

Data Table 3 Average Number of



As a class, compare the type of graph made for each data table.



### **Design Your Own**

## Developing a Measurement System

#### Goals

- Design an experiment that involves devising and testing your own measurement system for length.
- Measure various objects with the string measurement system.

#### **Possible Materials**

string scissors marking pen masking tape miscellaneous objects for standards

#### **Safety Precautions**



#### 🧶 Real-World Problem

To develop the International System of Units, people had to agree on set standards and basic definitions of scale. If you had to develop a new measurement system, people would have to agree with your new standards and definitions. In this lab, your team will use string to devise and test its own SI (String International) system for measuring length. What are the requirements for designing a new measurement system using string?

### 🧶 Form a Hypothesis

Based on your knowledge of measurement standards and systems, form a hypothesis that explains how exact units help keep measuring consistent.

#### Test Your Hypothesis

#### **Make a Plan**

- 1. Complete the safety form before you begin.
- **2.** As a group, agree upon and write out the hypothesis statement.
- **3.** As a group, list the steps that you need to take to test your hypothesis. Be specific, describing exactly what you will do at each step.
- **4.** Make a list of the materials that you will need.



### Using Scientific Methods

- **5. Design** a data table in your Science Journal so it is ready to use as your group collects data.
- **6.** As you read over your plan, be sure you have chosen an object in your classroom to serve as a standard. It should be in the same size range as what you will measure.
- Consider how you will mark scale divisions on your string. Plan to use different pieces of string to try different-sized scale divisions.
- **8.** What is your new unit of measurement called? Come up with an abbreviation for your unit. What will you name the smaller scale divisions?
- **9.** What objects will you measure with your new unit? Be sure to include objects longer and shorter than your string. Will you measure each object more than once to test consistency? Will you measure the same object as another group and compare your findings?



- 1. Make sure your teacher approves your plan before you start.
- **2.** Carry out the experiment as it has been planned.
- **3. Record** observations that you make and complete the data table in your Science Journal.

#### Analyze Your Data

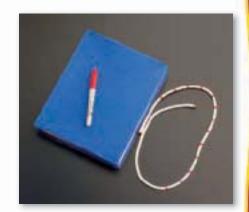
- **1. Explain** which of your string scale systems will provide the most accurate measurement of small objects.
- Describe how you recorded measurements that were between two whole numbers of your units.

#### Conclude and Apply

- Explain why, when sharing your results with other groups, it is important for them to know what you used as a standard.
- **2. Infer** how it is possible for different numbers to represent the same length of an object.



**Compare** your conclusions with other students' conclusions. Are there differences? Explain how these may have occurred.



# Science Länguage 15-5

# Thinking in Pictures: and other reports from my life with autism<sup>1</sup>

**By Temple Grandin** 

Temple Grandin is an animal scientist and writer who also happens to be autistic. People with autism are said to think in pictures.

I think in pictures. Words are like a second language to me. I translate both spoken and written words into full-color movies, complete with sound, which run like a VCR tape in my head. When somebody speaks to me, his words are instantly translated into pictures. Language-based thinkers often find this phenomenon difficult to understand, but in my job as equipment designer for the livestock industry, visual thinking is a tremendous advantage.

... I credit my visualization abilities with helping me understand the animals I work with. Early in my career I used a camera to help give me the animals' perspective as they walked through a chute for their veterinary treatment. I would kneel down and take pictures through the chute from the cow's eye level. Using the photos, I was able to figure out which things scared the cattle.

Every design problem I've ever solved started with my ability to visualize and see the world in pictures. I started designing things as a child, when I was always experimenting with new kinds of kites and model airplanes.

1 Autism is a complex developmental disability that usually appears during the first three years of life. Children and adults with autism typically have difficulties in communicating with others and relating to the outside world.

### **Understanding Literature**

**Identifying the Main Idea** The most important idea expressed in a paragraph or essay is the main idea. The main idea in a reading might be clearly stated, but sometimes the reader has to summarize the contents of a reading in order to determine its main idea. What do you think is the main idea of the passage?

#### Respond to the Reading

- 1. How do people with autism think differently from other people?
- 2. What did the author use to see from a cow's point of view?
- **3.** What did the author use for models to design things when she was a child?
- **4. Linking Science and Writing** Research the use of a scientific model. Write a paragraph stating the main ideas and listing supporting details.



Models enable scientists to see things

that are too big, too small, or too complex. Scientists might build models of DNA, airplanes, or other equipment. Temple Grandin's visual thinking and ability to make models enable her to predict how things will work when they are put together.

### **Reviewing Main Ideas**

#### Section 1 The Methods of Science

**1.** Science is a way of learning about the natural world, such as the hurricane shown below, through investigation.



- 2. Scientific investigations can involve making observations, testing models, or conducting experiments.
- **3.** Scientific experiments investigate the effect of one variable on another. All other variables are kept constant.
- **4.** Scientific laws are repeated patterns in nature. Theories attempt to explain how and why these patterns develop.

#### **Section 2 Standards of Measurement**

- **1.** A standard of measurement is an exact quantity that people agree to use as a basis of comparison. The International System of Units, or SI, was established to provide a standard and reduce confusion.
- **2.** When a standard of measurement is established, all measurements are compared to the same exact quantity—the standard. Therefore, all measurements can be compared with one another.

- **3.** The most commonly used SI units include length—meter, volume—liter, mass—kilogram, and time—second.
- **4.** Any SI unit can be converted to any other related SI unit by multiplying by the appropriate conversion factor. These towers are 45,190 cm in height, which is equal to 451.9 m.
- **5.** Precision is the description of how close measurements are to each other. Accuracy is comparing a measurement to the real or accepted value.



#### Section 3

#### **Communicating with Graphs**

- 1. Graphs are visual representations of data that make it easier for scientists to detect patterns.
- **2.** Line graphs show continuous changes among related variables. Bar graphs are used to show data collected by counting. Circle graphs show how a fixed quantity can be broken into parts.
- **3.** To create a circle graph, you have to determine the angles for your data.
- **4.** In a line graph, the independent variable is always plotted on the horizontal x-axis. The dependent variable is always plotted on the vertical y-axis.

FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review scientific processes.

#### **Using Vocabulary**

accuracy p. 14	mass p. 19
bias p. 10	model p. 11
constant p. 9	precision p. 14
control p.9	scientific law p. 12
density p. 19	scientific method p.7
dependent variab	ole p.9 technology p.13
experiment p.8	theory p. 12
graph p.22	variable p.9
hypothesis p.8	volume p. 18
independent vari	able p.9

Match each phrase with the correct term from the list of vocabulary words.

- comparing a measurement to the real or accepted value
- **2.** the amount of space occupied by an object
- **3.** application of science to help people
- **4.** the amount of matter in an object
- **5.** a variable that changes as another variable changes
- 6. a visual display of data
- **7.** a test set up under controlled conditions
- **8.** a variable that does **NOT** change as another variable changes
- 9. mass per unit volume
- **10.** an educated guess using what you know and observe

#### **Checking Concepts**

Choose the word or phrase that best answers the question.

- **11.** Which question **CANNOT** be answered by science?
  - A) How do birds fly?
  - **B)** How does a clock work?
  - **c)** Is this a good song?
  - **D)** What is an atom?

- **12.** Which is an example of an SI unit?
  - A) foot
- c) pound
- **B)** gallon
- **D)** second
- **13.** One one-thousandth is expressed by which prefix?
  - A) centi-
- c) milli-
- B) kilo-
- D) nano-
- **14.** What is SI based on?
  - A) English units
- c) powers of five
- **B)** inches
- **D)** powers of ten
- **15.** What is the symbol for deciliter?
  - A) dL
- c) dkL
- **B)** dcL
- **D)** Ld
- **16.** Which is **NOT** a derived unit?
  - A)  $dm^3$
- $\mathbf{C}$ ) cm<sup>3</sup>
- **B)** m
- **D)** g/mL
- 17. Which is NOT equal to 1,000 mL?
  - **A)** 1 L
- **c)**  $1 \text{ dm}^3$
- **B)** 100 cL
- **D)**  $1 \text{ cm}^{3}$

#### **Interpreting Graphics**

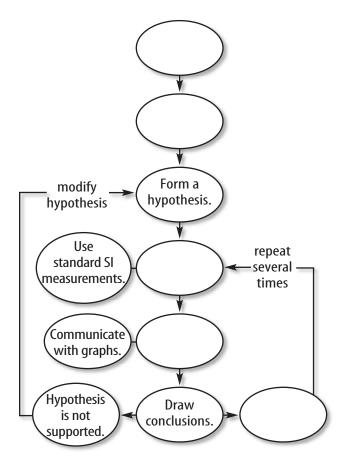
Use the photo below to answer question 18.





**18. Define** The illustrations above show the items needed for an investigation. Which item is the independent variable? Which items are the constants? What might a dependent variable be?

**19.** Concept Map Copy and complete this concept map on scientific methods.



#### Thinking Critically

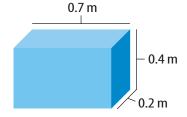
- **20.** Communicate Standards of measurement used during the Middle Ages often were based on such things as the length of the king's arm. How would you go about convincing people to use a different system of standard units?
- **21. Analyze** What are some advantages and disadvantages of adopting SI in the United States?
- **22. Identify** when bias occurs in scientific experimentation. Describe steps scientists can take to reduce bias and validate experimental data.

- **23. Demonstrate** Not all objects have a volume that is measured easily. If you were to determine the mass, volume, and density of your textbook, a container of milk, and an air-filled balloon, how would you do it?
- **24.** Apply Suppose you set a glass of water in direct sunlight for 2 h and measure its temperature every 10 min. What type of graph would you use to display your data? What would the dependent variable be? What would the independent variable be?
- 25. Form a Hypothesis A metal sphere is found to have a density of 5.2 g/cm<sup>3</sup> at 25°C and a density of 5.1 g/cm<sup>3</sup> at 50°C. Form a hypothesis to explain this observation. How could you test your hypothesis?
- **26.** Compare and contrast the ease with which conversions can be made among SI units versus conversions among units in the English system.

#### **Applying Math**

- **27.** Convert Units Make the following conversions.
  - **A)** 1,500 mL to L
- **c)** 5.8 dg to mg
- **B)** 2 km to cm
- **D)** 22°C to K
- **28.** Calculate the density of an object having a mass of 17 g and a volume of 3 cm<sup>3</sup>.

Use the illustration below to answer question 29.



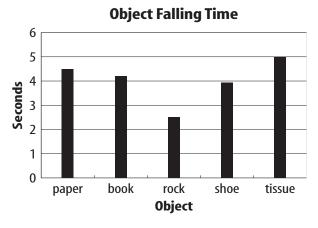
**29. Solve** Find the dimensions of the box in centimeters. Then find its volume in cubic centimeters.

## chapter Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### Multiple Choice

Students drop objects from a height and measure the time it takes each to reach the ground.



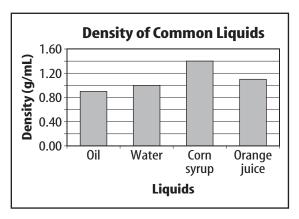
- **1.** What is the dependent variable in this experiment?
  - **A.** drop height
  - **B.** falling time
  - **c.** paper
  - **D.** shoe
- **2.** Which graph is most useful for showing how the relationship between independent and dependent variables changes over time?
  - A. bar graph
  - B. circle graph
  - **c.** line graph
  - **D.** pictograph

#### **Test-Taking Tip**

**Recheck Your Answers** Double check your answers before turning in the test.

- **3.** Which is a statement about something that happens in nature which seems to be true all the time?
  - **A.** theory
  - **B.** scientific law
  - **c.** hypothesis
  - **D.** conclusion
- **4.** Which best defines mass?
  - **A.** the amount of space occupied by an object
  - **B.** the distance between two points
  - **c.** the quantity of matter in an object
  - **D.** the interval between two events

Use the graph below to answer questions 5 and 6.

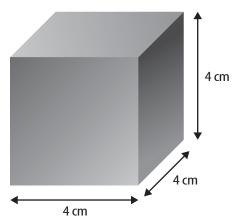


- **5.** Which two liquids have the highest and the lowest densities?
  - A. oil and water
  - **B.** oil and corn syrup
  - **c.** orange juice and water
  - **D.** corn syrup and orange juice

- **6.** Convert 615 mg to grams.
  - **A.** 0.00615 g
  - **B.** 0.615 g
  - **c.** 6.15 g
  - **D.** 61.5 g
- **7.** What does the symbol *ns* represent?
  - A. microsecond
  - B. millisecond
  - **C.** nanosecond
  - **D.** picosecond

#### **Gridded Response**

**8.** Calculate the volume of the cube shown.



#### Short Response

**9.** Describe several ways scientists use investigations to learn about the natural world. **10.** Why do scientists use graphs when analyzing data?

#### **Extended Response**

11. You are going on a hiking and camping trip. Space is limited, and you must carry your items during hikes. What measurements are important in your preparation?

Use the illustration below to answer question 12.



- **12.** What is the standard unit shown in this illustration? Why is it kept under cover in a vacuum-sealed container?
- **13.** Define the term *technology*. Identify three ways that technology makes your life easier, safer, or more enjoyable.
- **14.** Describe the three major categories into which science is classified. Which branches of science would be most important to an environmental engineer? Why?
- **15.** A friend frequently misses the morning school bus. Use the scientific method to address this problem.

2

#### BIG (Idea

People determine how scientific knowledge is used.

### 2.1 Science and Technology

MAIN (Idea Technology is the application of scientific knowledge to benefit people.

### 2.2 Forces that Shape Technology

MAIN (Idea Economic and social factors help determine how technologies are developed and used.

### 2.3 Developing Technology

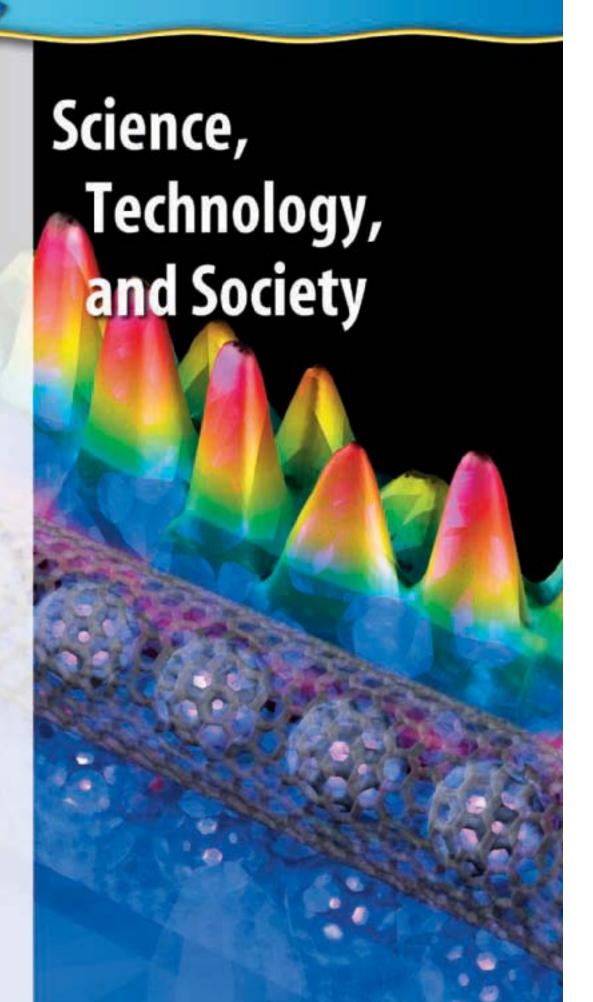
MAIN (Idea Engineers use a scientific approach to develop and test new technologies and products.

#### Peas in a Pod

What looks like peas in a pod are actually carbon atoms inside a tube also made of carbon atoms. The width of the tube is less than one-billionth the width of a human hair. Advancements in technology allow scientists to view and create these small-scale systems.

#### **Science Journal**

List five types of technology you have used today.



### **Start-Up Activities**



#### **Technology in Your Life**

You probably do not think about how technology affects your life. You use many types of technology every day without realizing it. How much technology do you use?

- 1. Complete the safety form.
- 2. Make a list of everything that you do from the time that you get home from school until you go to bed.
- **3.** Circle the items on the list that involve some type of technology.
- **4.** Select two of the items and identify the technologies involved in the item. For example, the technologies involved in a television may be the wiring or the wave that transports the signal.
- **5. Thinking Critically** Write a list of activities that you could do after school if none of the technologies that you listed were available.



Preview this chapter's content and activities at gpescience.com



Science and Technology Make the following Foldable to help organize information about science and technology.

Fold a sheet of paper vertically in half from top to bottom.



**STEP 2 Fold** in half from side to side with the fold at the top.



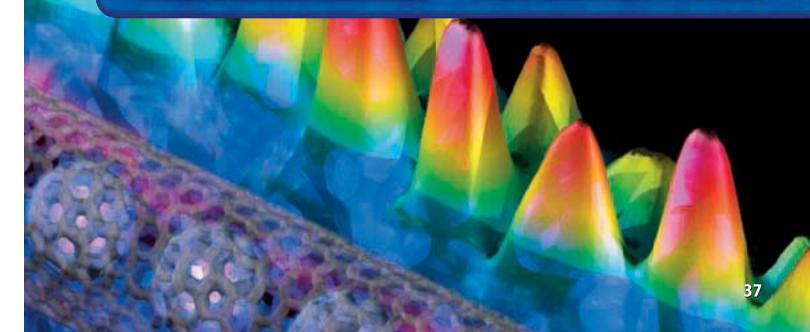
STEP 3 Unfold the paper once. Cut only the fold of the top flap to make two tabs.



**STEP 4 Turn** the paper vertically and label the flaps *Science* and *Technology*.



**Read for Main Ideas** As you read the chapter, list the characteristics of science and technology under the appropriate flap.



# **Science and Technology**

#### **Reading Guide**

#### What You'll Learn

- Discuss how the study of science leads to a better understanding of natural events.
- **Describe** the different types of technology.
- **Explain** why the value of technology may differ for different people and at different times.

### Why It's Important

Science provides information, insight, and analytical skills to help people understand the possible causes and effects of natural events.

#### Review Vocabulary

technology: the application of science to help people

#### **New Vocabulary**

agricultural biotechnology



**Figure 1** Physicians in the Middle Ages treated people who had the plague. The beak in the protective mask contains a mixture of materials to filter the "bad air." **Contrast** the methods used to help prevent the spread of diseases during the Middle Ages against methods used today.

### **Scientific Discovery**

The study of science usually leads to a better understanding of the world around you. For example, some scientists in the Middle Ages believed that the plague was spread by breathing "bad air". Doctors wore protective clothing to protect themselves, as shown in **Figure 1.** Various measures were taken by local doctors to rid homes of this "bad air" in an attempt to stop the plague. History is full of breakthroughs in science that have changed the course of human history. One such breakthrough is the discovery that microorganisms cause illnesses and disease. Before the mid-1800s, people had no idea that microorganisms caused many human illnesses. Many diseases were easily passed from person to person because people had no idea why the disease was spreading.

In the mid-1800s, Louis Pasteur, a French scientist, discovered the cause of most infectious diseases. He informed the public that microorganisms brought about infections and diseases. Knowing how infectious diseases spread, Alexandre Yersin, a bacteriologist, traveled to Hong Kong. A plague epidemic was underway. He was hoping to isolate the bacteria that caused this disease. In 1894, Yersin was able to isolate the microbe that caused the disease. Once scientists discovered what was causing the disease, they could focus on how the disease spread through the population. It took another four years before scientists discovered that fleas spread this microbe to humans.

#### **Scientific Insight**

Once scientists found the source of the plague, scientists brought the information to the public's attention. The information provided an explanation of why the plague occurred. Outbreaks of the plague took place throughout history. One outbreak in the 14th century killed approximately one-fourth of the population of Europe. When people clearly understood why the disease was spreading, actions could be taken to stop the disease.

**Disease Prevention Today** The fact that microbes spread illnesses is not news today. Young children are taught to wash their hands before eating. Restrooms contain water, soap, and towels to use to prevent the spread of microbes. Sterile bandages, cleansers, and medicines are sold in stores for use on injuries to prevent infection. Doctors and hospitals use sterile instruments for each patient to prevent the spread of disease. These measures are taken now because we know how contagious diseases are spread from person to person and what causes infections in wounds.

Weather Forecasting Scientific insight also is used in many other ways, including weather forecasting. If you had lived in the 1800s, you only could have guessed the type of weather that was approaching by looking at the sky. Today, meteorologists use a variety of specialized instruments to predict the weather. Their instruments can detect approaching conditions that are dangerous. With advance warning, people can seek shelter or

leave areas that are threatened by violent weather. **Figure 2** demonstrates the importance of forecasting dangerous weather conditions.

Science has changed the way people respond to natural events, such as the spread of microbes and hazardous weather. The study of science can lead to an understanding of why a natural process occurs. Once there is a clear understanding, people learn how to respond to the event and try to control the outcome.



What is another example of science being used to change people's behavior?

**Figure 2** In 1900, a hurricane struck Galveston, Texas, killing about 8,000 people. Today earlywarning systems alert people of an approaching storm, which saves many lives.

**Identify** a type of hazardous weather that occurs in your area that requires an early-warning system.





#### **Researching the Past**

#### **Procedure**

- **1.** Complete the safety form.
- 2. Prepare at least five questions to ask a senior citizen about technology when he or she was a teenager.
- **3.** Perform the interview.
- **4.** Write the responses to your questions in your Science Journal.

#### **Analysis**

Compare and contrast at least five differences in technology between then and now.

#### What is technology?

The terms *science* and *technology* often are used interchangeably. However, these terms have very different definitions. Science is an exploration process. Scientific processes are used to gain knowledge to explain and predict natural occurrences. Scientists often pursue scientific knowledge for the sake of learning new information. There may or may not be a plan to use the knowledge.

When scientific knowledge is used to solve a human need or problem, as shown in **Figure 3**, the result is referred to as technology. Technology is the application of scientific knowledge of materials and processes to benefit people. Given this definition, is an aspirin tablet technology? Is a car technology? What about the national highway system? Although these examples appear to be very different, they all represent examples of technology. Technology can be:

- any human-made object (such as a radio, computer, or pen),
- methods or techniques for making any object or tool (such as the process for making glass or ceramics),
- knowledge or skills needed to operate a human-made object (such as the skills needed to pilot an airplane), or
- a system of people and objects used to do a particular task (such as the Internet, which is a system to share information).

**Technological Objects?** The value of a technological object changes through time. What is considered technology today

> might be considered an antique tomorrow. For example, special feathers called quills were used long ago to write with ink. The quill pen was the height of technology for over one thousand years. Then, in the middle of the nineteenth century, metallic pens and writing points came into use. The modern ballpoint pen was not widely used until the 1940s.





What are five additional objects that are considered technology?

**Figure 3** This figure shows technology. This image is a technological object. The knowledge needed to create and interpret this image is technology. **Identify** the technologies used to make a car.



**Figure 4** Technology changes through time. As new scientific knowledge and techniques are learned, the processes used to create objects change. **Identify** another process used to create objects that has changed through time.

**Technological Methods or Techniques** Just as writing instruments have changed through time, so have techniques for performing various tasks. **Figure 4** shows the results of how the techniques for making books have changed. Long ago, people would sit for hours copying each page of a book by hand. They used whatever writing materials were available during that time. Books were expensive and bought only by the very rich. Today, books can be created in different ways. They can be made on a computer, printed with a computer printer, and bound with a simple machine. Modern printing presses are used to produce the majority of books used today, including your textbook.

The methods used to print books have changed through time. Each technique is technology. Other techniques that characterize technology are using a compact disc to store information, using a refrigerator to preserve food, and using email to correspond with friends.

**Technological Knowledge or Skills** Technology also can be the knowledge or skills needed to perform a task. For example, computer skills are needed to use the software that is used to make books and other documents. Printing press operators must use their skills to print books successfully. Anytime a complex machine is used to perform a task, technological skills must be used by the operator.

**Technological Systems** A network of people and objects that work together to perform a task also is technology. One example of this technology is the Internet. The Internet is a collection of computers and software that is used to exchange information. A technological system is a collection of the other types of technology that are combined to perform a specific function. The airline industry is an example of technological systems. This industry is a collection of objects, methods, systems, knowledge, and procedures. The airports, pilots, fuel, and ticketing process form a technology system that is used to move people and goods.

#### **Global Technological Needs**

The example of how books were made explained how technology has changed through the ages. The value of technology may differ for different people and at different times. The technology that is valued in the United States is not necessarily valued in other parts of the world. The needs for technology are different in developing and industrialized countries.

**Developing Countries** The people of some countries work hard for basic needs such as food, shelter, clothing, safe drinking water, and health care. For example, the Kenyan family shown in Figure 5 lives without electricity and running water in their home. Health care is limited for many families in Africa. The lack of health care results in a life expectancy for rural Kenyans to be in the mid-forties. Tropical diseases, as well as infection by the human immunodeficiency virus (HIV) are a severe problem. In addition, droughts often cause shortages of food supplies in some parts of this country.

Technological solutions in developing countries focus on supplying basic needs for these families. Technology that would supply adequate and safe drinking water and food supplies would be valued. Increasing the accessibility of basic health care would improve the quality of life and increase the life expectancy in developing countries. The technology valued by rural people contrast with the technology valued by people in industrialized Kenyan cities.



What are two examples of technology that would be valued in developing countries?



**Figure 5** The technological needs of this Kenyan family center around providing the basic needs for survival, such as provisions for safe water and food supplies, health care, education, and a safe environment in which to live and work.

**Industrialized Countries** The United States is considered an industrialized country. Technology gives people the ability to clean polluted waters. Improving the quality of the food supply is also valued. But the level of urgency and focus appears to differ in developing countries. Most areas of the United States have adequate and safe water and food supplies. Most homes have electricity and running water. Quality health care is available to many people. The life expectancy of Americans is the late-seventies.

Look at the home in **Figure 6** and compare it to the home shown on the previous page. Does one of the homes have more technology? Look at the materials used to build each home. The materials used to build the home in **Figure 6** are technology, too.

Because the needs for survival are met in industrialized nations, money often is spent on technology. Technology is designed to improve the quality of life of individuals. Most homes in the United States contain many different types of technology, including computers, telephones, and televisions. People living in industrialized countries may value faster and faster computers. They may value small devices such as compact discs that store large amounts of information. Advances in health care can improve the quality of life due to the ability to cure diseases. Money is spent on such medical procedures as cosmetic surgery to remove wrinkles, and eye surgery so that a person no longer has to wear glasses.

**Figure 6** The basic needs for survival are available in industrialized nations. In these countries, value is placed on technology that improves the quality of life such as devices that make tasks easier and devices that provide entertainment. **Describe** three technological objects that you value that would be of less value to the Kenyan family on the previous page. Explain your answers.

#### **Contrasting Needs**

As you can see, the human needs for developing and industrialized countries are very different. Both developing and industrialized countries value technologies that supply basic human needs as discussed in **Figure 7.** The actual technology required in each country may be very different.



## NATIONAL VISUALIZING TECHNOLOGY GEOGRAPHIC SUPPLYING BASIC NEEDS

#### Figure 7

echnology is used to help supply the basic requirements of people across the globe. Many of life's necessities that we take for granted in the United States are lacking or inadequate in other countries.

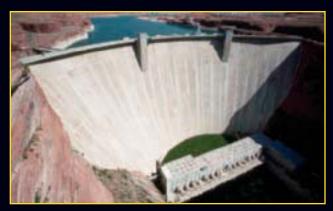


Water Treatment Polluted water can cause diseases. Treating the water with chlorine kills germs.



▲ Modern Agriculture Farming with tractors on vast fields and using pesticides and specially engineered seed can increase the amount of food a country produces.

Vaccines Diseases like polio, measles, and tetanus kill hundreds of thousands of people a year. Vaccines cause the human body to make antibodies for a specific bacteria or virus. If this bacteria or virus enters the body, the antibodies destroy it.



Power Plants Electricity is necessary for many technologies. Electricity can be produced in many ways including burning coal, using moving water, absorbing the heat of solar rays, and using heat deep in the earth.



▲ Transportation Systems Technology allows countries to build roads, airports, and canals that let food, medicine, and information travel quickly to where it is needed.

**Bioengineering and Food** Can technology stop world hunger and starvation? Agricultural biotechnology can increase the yields of farm crops. It also can increase the nutritional value of the food produced. **Agricultural biotechnology** is a collection of scientific techniques, including genetic engineering, that are used to create, improve, or modify plants, animals, and microorganisms. For example, changing the DNA of a plant such as corn can improve its tolerance to drought. Other benefits could make it disease and insect resistant, or improve its nutritional value. The end result may be a higher crop yield and a product that provides more nutritional value per serving.

Genetically altering plant species is a highly controversial practice. Some people argue that the practice is too dangerous. They argue that humans should not alter species that occur naturally on Earth. Others argue that new species could harm natural ecosystems. New crops could pose human health risks such as food allergies or toxins.

A discussion also exists over whether more food really is needed to feed the world population. One argument is that enough food is produced, but it is not equally distributed throughout the world. As you can see, using technology to solve human problems is not always an easy task. Often there are many obstacles and issues involved.



#### **Topic: Biotech Foods**

Visit gpescience.com for Web links to information about agricultural biotechnology and biotech foods.

**Activity** Create a pamphlet explaining the risks and benefits of biotech foods.

#### section

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#### **Summary**

#### **Scientific Discovery**

• The study of science leads to a better understanding of natural events that occur.

#### **Scientific Insight**

- Once there is an understanding of why a natural process occurs, people learn how to respond to the event and try to control the outcome.
- Scientific insight changes human behavior.

#### What is technology?

- Technology can be an object, a technique, a skill, or a system.
- The value of technological objects varies over time.

#### **Global Technological Needs**

• Technological needs vary around the world.

#### Self Check

- 1. **Describe** a situation in which scientific insight changed people's understanding, resulting in behavior change in response to a natural event or process.
- **2. Classify** List the types of technology and give at least two examples of each type.
- **3. Explain** why the types of technology valued varies from location to location.
- 4. Think Critically Cell phones are a technology that is popular throughout the world. Would this technology be of use in rural areas of the world? Explain your answer.

#### **Applying Math**

 Calculate Approximately 38 million people are infected with HIV worldwide. Two-thirds of this group lives in sub-Saharan Africa. Calculate how many sub-Saharans are affected.

# **Forces that Shape Technology**

#### **Reading Guide**

#### What You'll Learn

- Discuss how funds for science research come from the federal government, private industries, and private foundations.
- **Explain** how consumers affect technological development.
- **Describe** the importance of responsible technological development.

#### Why It's Important

Society and economic forces influence which technologies will be developed and used.

#### Review Vocabulary

**ecosystem:** a complex community of organisms that function together in a particular environment

#### New Vocabulary

society



Figure 8 Consumers often decide which technologies will be developed. If consumers do not purchase a product, additional money usually will not be spent on the production or improvement of the product.

#### **Social Forces that Shape Technology**

Science and society are closely connected. **Society** is a group of people that share similar values and beliefs. Discoveries in science and technology bring about changes in society. In turn, society affects how new technologies develop. The development of technology is affected by society and its changing values, politics, and economics.

In the past 100 years, attitudes in the United States have changed toward automobiles. Many people were able to own cars due to the changes in technology and manufacturing. As car ownership increased, so did fossil-fuel consumption. With rising gasoline prices, some consumers began buying more fuel-efficient cars. The automotive industry has researched and developed technologies that make cars more fuel-efficient. Today we have hybrid cars that use both gasoline and electricity.

**Consumer Acceptance** Purchasing technology is a direct way in which people support the development of technology, as shown in **Figure 8.** For example, if consumers continue to purchase fuelefficient cars, additional money will be spent on improving the technology. If consumers fail to buy a product, companies usually will not spend additional money on that type of technology.

**Personal Values** People will support the development of technologies that agree with their personal values, directly and indirectly. For example, people vote for a congressional candidate based upon the candidate's views on various issues. This is an indirect way in which people's personal values influence how technology projects receive funding. People support the development of technology directly when they give their money to organizations committed to a specific project, such as cancer research.



How do the personal values of consumers influence which technologies will be developed?

### **Economic Forces that Shape Technology**

Many factors influence how much money is spent on technology. Before funding is given for a project, several questions should be answered. What is the benefit for this product? What is the cost? Who will buy this product? All these questions should be answered before money is given for a project. Various methods exist to fund new and existing technology.

**Federal Government** One way in which funds are allocated for research and development of technology is through the federal government. Every year, Congress and the president place large amounts of money in the federal budget for scientific research and development. These funds are reserved for specific types of research, such as agriculture, defense, energy, and transportation. This money is given to companies and institutions in the form of contracts and grants to do specific types of research. Citizens can influence elected officials by telling them how they want the official to vote, as shown in **Figure 9.** 

**Private Foundations** Some scientific research is funded using money from private foundations. A private foundation, which is an organization not associated with the government, is a group of people who work together for a common goal. Funds are raised for various types of disease research, such as breast cancer and muscular dystrophy. Money is raised by events such as races and telethons. Many private foundations focus on research for a specific cause.

**Figure 9** Participating in the political process is one way in which people can influence which technologies are developed and which are not.

**Explain** how voting for someone in the Congress influences which technologies will be developed.



# Evaluating the Benefits and Consequences of Technology

#### Procedure

- 1. Complete the safety form.
- 2. Choose a technology that you value and do not want to live without.
- **3.** Make a two-column table. Label one column *Benefits* and the other column *Consequences*.
- **4.** Provide at least three entries for each column.

#### **Analysis**

- **1.** Do the benefits of the technology outweigh the consequences? Explain.
- Infer who funded the development of your technology. Explain.
- 3. Infer how you may influence future funding on this type of technology.





**Environmental Protection Agency** The purpose of the EPA is to protect human health and the environment. The EPA was established in 1970 by the White House and Congress. Cleaner air and water, along with cleaner land, were things that U.S. citizens have demanded. Prior to the establishment of the EPA, the government had no organized method to reduce pollutants. Research the water quality for your city or state.

**Private Industries** Research and development also is funded by private industries. Industries budget a portion of their profits for research and development. Investing in research and development often makes money for the company. Bringing new products to the marketplace is one way companies make profits.

#### **Responsible Technology**

Humans have the ability to invent tools and processes that can have an impact on other living things. Humans are part of many ecosystems on Earth. It is important that any technology that is used does not destroy the environment, as shown in **Figure 10.** It is important that both positive and negative consequences of a particular technology be considered.

**Environmental Issues** Sometimes the consequences of technology are known, but the benefits are perceived to outweigh the risks. One example of technology that has both positive and negative consequences is gasoline-powered cars. Gasolinepowered cars give the benefit of reliable transportation. The negative consequences are the environmental problems created by drilling for oil, air pollution, and disposal of unwanted cars. The disposal of used petroleum products, such as motor oil, also is a problem.

Sometimes the benefits of technology are known immediately, but the consequences are not known for a period of time. For example, at one time, the pesticide DDT was eagerly accepted by people. It killed insects that were damaging agricultural crops.



The fact that DDT was damaging the environment was not known immediately. When the damage was discovered, DDT was banned and other pesticides were developed. Consumers and voters have a responsibility to weigh the benefits and consequences of technology. They play a major role in determining which technologies are used and which are rejected.

Figure 10 In March 1989, approximately 42,000 kiloliters of oil were spilled in Prince William Sound, Alaska. Animals, such as ducks and birds, are affected by human-made environmental disasters.



**The Chernobyl Accident** Possibly the worst technological accident in modern

times occurred on April 26, 1986, at the Chernobyl nuclear power plant in the Ukraine. Large areas of land were contaminated and more than 400,000 people had to be relocated. The city of Pripyat had to be abandoned, as shown in **Figure 11.** An accumulation of radioactive fallout in the upper layers of soil has destroyed important farmland. Groundwater and surface waters

were contaminated. Some water wells had to be sealed. Structures had to be built to prevent rivers and streams in the area from contaminating additional rivers in the watershed, which led to the Black Sea.

The radiation also affected many animals and plants around Chernobyl. As the radiation diminished, plants and animals started to repopulate the area.



Why did the residents near the accident have to move?

**Figure 11** This town once was home to about 45,000 residents. It is now abandoned because radioactive contamination has made it unsafe to live in. **Identify** possible health effects that Ukrainians faced.



#### **Applying Science**

### What impact does the accident at Chernobyl have on the future of nuclear power?

The nuclear accident at Chernobyl in 1986 demonstrates the far-reaching impact of a nuclear disaster. Not only were the residents and environment surrounding the facility influenced, but nuclear fallout was spread across most of the northern hemisphere. Parts of the USSR and Europe were seriously affected.

#### **Identifying the Problem**

Many countries, including the United States, use nuclear power as a source of electric power. Is it important for industrialized countries, such as the United States, that have vast resources and knowledge about nuclear power generation, to assist developing countries in their nuclear power generation programs?

#### Solving the Problem

- 1. What are the benefits and consequences of allowing developing countries that do not have the experience that developed countries have to develop nuclear power on their own?
- 2. What are the benefits and consequences of assisting developing countries?



### **Topic: Morals and Ethics** in Science

Visit gpescience.com for Web links to information about morals and ethics in science.

**Activity** Choose a topic and write an essay describing the moral and ethical arguments surrounding the topic.

**Moral and Ethical Issues** When people need to distinguish between right and wrong, what is fair, and what is in the best interest of all people, moral and ethical issues are raised. Ethical issues in science pose questions and establish rules about how scientific hypotheses should be tested and how society should use scientific knowledge.

Ethics help scientists establish standards that they agree to follow when they collect, analyze, and report data. Scientists are expected to conduct investigations honestly and openly. Honesty is important because scientists share the results of their investigations with each other. As a result, one scientist's dishonesty can harm the investigations of many scientists.

Other ethical questions in science concern the use of animals and humans in scientific investigations. In the past, the inhumane treatment of humans and animals in experiments has led to public outcry. For example, human test subjects have been subjected to experiments against their will, or without informing them of risks associated with the research or the true nature of the experiments. Ethical questions about these practices helped to create laws and guidelines to prevent unethical treatment of both humans and animals in scientific research.

# section

# review

### **Summary**

### **Social and Economic Forces that Shape Technology**

- Societal and economic forces influence which technologies will be developed and used.
- The federal government, private foundations, and private industries fund research and development of technology.
- Consumers influence which technologies will be developed by their voting and buying habits.

#### Responsible Technology

- Humans must be responsible in their technological choices because the technology may have an enormous impact on other living things and the environment.
- The risks and benefits of technology must be considered before developing and using it.
- Consumers and scientists must consider moral and ethical issues when choosing which technologies should be developed.

### Self Check

- 1. Describe how private citizens have a voice in which projects the federal government will fund.
- 2. Explain how you can influence whether or not funding will be spent on developing certain technology.
- 3. **Describe** a situation in which technology had unexpected consequences.
- 4. Think Critically Many products carry a message on their label that no animals or humans were used in the testing of the product. Is this good or bad for the consumer? Explain your answer.

### **Applying Math**

5. Use Percentages In 2001, approximately \$41 million was spent by the Department of Defense for Research, Development, Test, and Evaluation. If the total amount of money spent by the department was over \$305 million, what percent of the defense budget does this represent?



# Who contributes CO<sub>2</sub>?

Many scientists believe that Earth's surface temperature is rising because of increasing levels of heat-trapping carbon dioxide, CO<sub>2</sub>, in Earth's atmosphere. The combustion of fossil-fuels contributes CO<sub>2</sub> to Earth's atmosphere.

# Real-World Problem —

Which countries produce the most carbon dioxide from the combustion of fossil fuels?

#### Goals

- Compare and contrast the total carbon dioxide emissions from selected countries.
- **Calculate** the average annual per capita amount of carbon dioxide for each country.
- Form a hypothesis that explains the amount of carbon dioxide produced by each country.

#### **Materials**

Science Journal

pen or pencil

### Procedure =

- 1. Complete the safety form before you begin.
- Copy and complete the data table in your Science Journal by calculating the amount of carbon dioxide produced per person for each country.
- 3. Formulate a hypothesis that explains the amount of carbon dioxide produced by the inhabitants of the countries listed in the table. For each country, consider the following factors: size; population density; transportation requirements; heating and

Countries CO <sub>2</sub> Emissions			
Country	CO <sub>2</sub> Emissions (millions of tons of carbon)	Total Population (millions of) persons)	CO <sub>2</sub> Produced (tons/person)
United States	1,446.8	263.8	
China	918.0	1,210.0	
Russian Federation	431.1	149.9	
Japan	318.7	125.5	
India	272.2	936.5	
Canada	111.7	28.4	
France	98.8	58.1	

cooling requirements; development and industry; means of generating electricity.

# Conclude and Apply

- **1. Graph** the data of carbon dioxide produced per person using a bar graph.
- **2. Think Critically** Why might more developed, industrial countries have more carbon dioxide produced per person?
- **3. Evaluate** Did the results obtained from your calculations support your hypothesis?

# Communicating Your Data

Compare your bar graphs with those of other students. Discuss any differences, particularly if some students used computer graphing programs to prepare their graphs.

# **Developing Technology**

## **Reading Guide**

### What You'll Learn

- Discuss how the roles of a scientist and an engineer differ.
- **Explain** how technological problems often create a demand for new scientific knowledge.
- Describe the general process used to find technical solutions to problems or human needs.

# Why It's Important

Understanding how technology is developed can help you make better decisions as a consumer.

### Review Vocabulary

**system:** a group of devices that work together to perform a specific function

### **New Vocabulary**

- engineer
- constraints
- computer simulation
- prototype
- pilot plant
- control system

# **Scientists and Engineers**

How do a scientist and an engineer differ? This may seem to be a very odd question, but it is important to learn the roles of these two types of professionals. Recall that a scientist is someone who has knowledge about science. He or she works to learn more information about science. Scientists may not know how or if the results of their work will be used, but they pursue knowledge for the sake of learning new things.

Scientists have knowledge of scientific principles. Most scientists have some knowledge of basic chemistry, physics, and biology. Many scientists specialize in one area of science. For example, a scientist may have a chemistry background but specialize in Earth science. This scientist will study the chemical and physical changes that occur on Earth. An Earth scientist

> may specialize even further and study topics such as glaciers, earthquakes, or volcanoes.

> Scientists often work in research laboratories doing research. In addition, scientists also work in the field, as shown in **Figure 12.** An Earth scientist is an example of a scientist that would conduct investigations and research in the field, as well as in the laboratory.





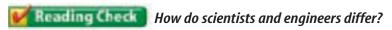
What is a scientist?

Engineers A researcher who is responsible for bringing technology to the consumer is called an engineer. Using scientific information or an idea, an engineer creates a way to solve a problem or to produce a product. For example, decreasing petroleum deposits and high prices for gasoline have created a demand for cars that get better gas mileage. Engineers are

working to improve an engine called a hybrid. The hybrid engine operates on electricity and gasoline or diesel to power the car. Fuel efficiency increases by combining the two power sources. Cars currently are available using this technology. As this example demonstrates, consumers want cars with better gas mileage. Engineers worked to create technology that would satisfy this consumer demand.

Technological problems often create a demand for new scientific knowledge. Time and money are devoted to finding new scientific information, which makes it possible for scientists to extend their research in a way that advances science. Many unexpected discoveries happened when scientists were looking for a technical solution. In addition, new technology often creates a need for even more technology, as shown in **Figure 13.** 

Engineers not only design automobiles, they work in many areas of science. There are aeronautical, aerospace, biomedical, chemical, computer, electrical, mechanical, and many other types of engineers. At some point of the manufacturing process, engineers are involved in the development of the products you use every day.





**Figure 13** New technology often creates a demand for even more technology. Many technological advances have been made in the automobile since 1950. **Identify** at least three different technological advances that have been made in the automobile since 1950.



Young Owl Gets Help Technology can be used in unusual ways. A young, great-horned owl was observed sitting on a fence for several days without moving. It seems the owl could not see and could not search for food. Veterinarians removed the owl's cataracts and fitted the owl with new artificial lenses. The owl recovered and was returned to the wild. Research other medical procedures that can be used to help animals.

### **Finding Solutions**

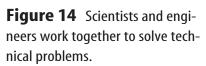
Scientists and engineers work together to find technological solutions, as shown in **Figure 14.** They often use a system much like the scientific method. The general process is outlined in this section. However, there are many variations to this procedure, just as there are many kinds of technical problems.

**Identifying the Problem** The first step in finding a technical solution is to define clearly the problem that you are trying to solve. The problem must have a narrow enough focus so that a solution is possible. For example, it would not be helpful to define the problem as, "Create and build a new vehicle." This definition of the problem is too broad. What type of vehicle is needed? Should the vehicle be designed to carry passengers or heavy loads or both? What type of fuel should the new vehicle use? What types of materials should be used to construct the vehicle? Is there a market for the vehicle once it is built? All of these questions and many more should be answered in the definition of the problem. A better statement of the problem may be, "Build a new passenger vehicle from readily available materials that has an improved gas mileage of at least 20 percent over current, similar-size models and is competitively priced."

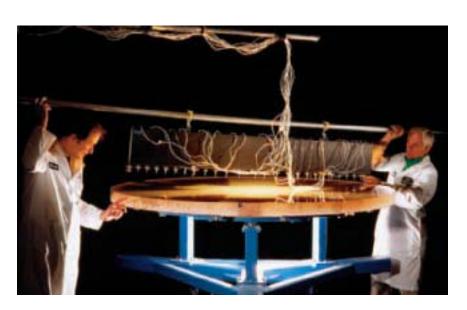
**Proposing Solutions** Once the problem is clearly defined, the search for the solution can begin. This is not always an easy process. There are many factors to consider when searching for the best solution to a problem. The best solution must be found while working with many limitations.



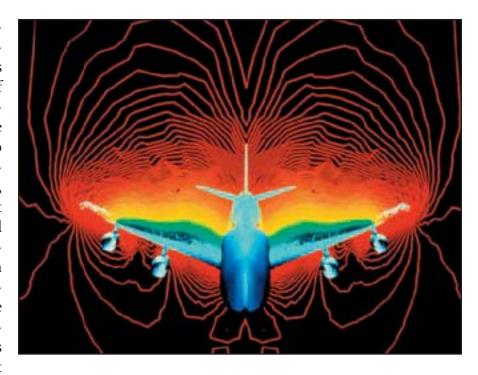
Why is it important to have a clearly defined problem?



**Identify** the type of system scientists and engineers use to find technological solutions.



**Constraints** Design restrictions for products from outside factors are known as constraints. Examples of constraints are cost, environmental impact, and available materials. Constraints also include limited time to complete the task, limited funding, and design changes that must be made to satisfy laws and regulations. In addition, working with too little information or technical data can be constraints. Some designs may be perfect solutions but they cannot be built. Some materials may not be available or do not



exist. Money may not be available. The solution to the problem may be a compromise because of many design constraints.

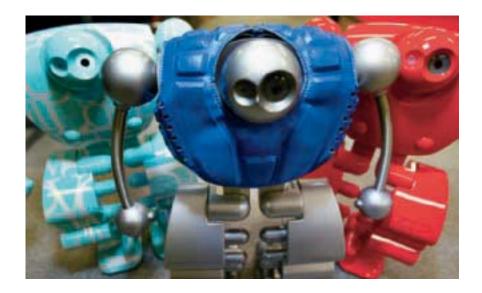
**Performance Testing** Once design ideas are accepted, drawings or models usually are constructed. These are carefully evaluated to identify possible design flaws. It is important to find design flaws as early in the process as possible. The later a design flaw is found in the process, the more expensive it is to correct.

After the drawing or model has been thoroughly evaluated, the design must be tested to make sure everything operates as planned. Many ways exist to performance test a design. The type of performance test used depends upon the design. For example, a chemical process may be tested initially by using a computer simulation. A computer simulation uses a computer to imitate the process to collect data or to test a process or procedure. Computer software is designed to mimic the processes in the design, as shown in Figure 15.

Complying with Laws and Regulations Local communities, states, and the federal government have laws and regulations regarding manufacturing processes, products, or buildings. These regulations often cover topics such as worker safety, environmental protection, product transportation, and how pleasing the manufacturing facility looks in the community. Products also must meet ethical or moral standards in their production, testing, and use. All of these factors must be considered when designing technology.

**Figure 15** This is a computer simulation of an aircraft in a wind tunnel. The lines and colors surrounding the aircraft show airflow and turbulence. Scientists who use computer simulation can work to improve the aircraft design. **List** other ways that a computer simulation can be used.

**Figure 16** This robot, which is 39 cm tall, can be controlled by a cellular phone or by voice commands. The robot can be used in schools to teach about engineering and computer programming. **Explain** why it is important to make a prototype of a new product.





Flight-Test Engineer

One of the crew members responsible for flight-testing an airplane or helicopter prototype is a flight-test engineer. The flight-test engineer is responsible for planning the test, acquiring the test equipment, writing the test plan, conducting the test, and then writing the test report. Research the educational requirements of a flight-test engineer.

**Prototypes and Pilot Plants** Constructing a prototype or manufacturing in a pilot plant are methods of performance testing. A **prototype** is a full-scale model that is used to test a new product such as a new car design or a new airplane product. A prototype, as shown in **Figure 16**, is the first full-scale product that is built. A pilot plant is a smaller version of the real production equipment that closely models actual manufacturing conditions. A pilot plant would be used to test a new manufacturing process, such as a production line to produce a new medicine.

**Limiting System Failure** Performance testing is one way to limit system failures. A system is a group of devices that work together to perform a specific function. Other ways to limit system failures are to put redundant systems within a design. A redundant system performs the same function within a design. These systems are used for important processes that would force the entire system to shut down if there is a failure. When redundancy is built into the design, if one part fails the other system will take over, keeping the entire system from failing.

Control systems, such as a fail safe system, also are incorporated into designs to keep the system from failing. A **control system** is a device or collection of devices that monitors a system. This device makes corrections to keep the system operating at preset conditions. A simple control system is the thermostat on an air conditioner or heater. An air conditioner thermostat turns the unit on when the air temperature rises to a preset high temperature. When the air temperature drops to the preset low temperature, the unit is turned off. Control systems can be simple, like a thermostat, or very complicated, like an elaborate computer system that controls heating and cooling. The purpose of control systems is to keep the system operating at desired conditions.

**Intellectual Property** Once a new product is introduced, it is important that a company protects its investment. Research and development of a new product is costly. Often, it takes years to bring a new product to the consumer. Companies protect their rights to sell their new product or process by applying for a patent. A patent is a legal document granted by the government giving an inventor the exclusive right to make, use, and sell an invention for a specific number of years. In the United States, a new patent lasts for 20 years. A patent allows a company to get the money back that they have spent on creating the new product or process.

A patent is one example of intellectual property. Intellectual property is any type of creative work that has financial value and is protected by law. Patent laws protect technological inventions. Copyright laws protect literary and artistic works such as music, plays, poetry, and novels. The compact discs shown in Figure 17 are examples of copyrighted products. Trademark laws protect words or symbols that identify brands, goods, or services in the marketplace.



Figure 17 Music compact discs are copyrighted. Copyright protection lasts for the author's life plus an additional seventy years after the author's death.



What are three types of intellectual property, and can you give an example of each type?

### section review

### **Summary**

### **Scientists and Engineers**

- Scientists seek new scientific knowledge, but they may not have a plan to use that knowledge.
- Engineers use science to find solutions to problems or human needs.
- Technical problems often create a demand for new scientific knowledge.

#### **Finding Solutions**

- Scientists and engineers often work together to solve technical problems.
- Performance testing often is conducted using models and computer simulations to reduce the chance of system failure.
- Intellectual property such as technology, music, and symbols that identify products is protected by law.
- Companies protect their investment in technology with a patent.

#### **Self Check**

- 1. Compare and contrast the roles of scientists and engineers.
- 2. **Describe** a specific situation in which new technology created a demand for even more technology.
- **3. Describe** Briefly describe the general process that is used to find technological solutions.
- **4. Think Critically** Some foreign countries do not have intellectual property laws. It is common for people in these countries to illegally manufacture goods that are protected in the United States and sell them to consumers. Explain how this financially harms companies in the United States as well as the consumer.

### **Applying Math**

**5. Use Percentages** The U.S. Customs and Border Protection made 6,500 seizures of merchandise in violation of intellectual property rights in the year 2003. This was an increase of about 700 seizures over the previous year. What was the percentage increase in the number of seizures from 2002 to 2003?



# **Model and Invent**

# Care P\( \overline{\pi} \) ckage

### Goal

- Model packaging and shipping a product for consumer interest.
- Calculate the cost to produce a consumer product.
- Test your packaging design to see if it keeps the snacks from being damaged.

### **Possible Materials**

shoe box assorted snack foods packing peanuts shredded newspaper packing tape wrapping paper markers

### **Safety Precautions**



## 🧶 Real-World Problem

Suppose you are a young businessperson with a new idea for a product. You are going to create a care package for students to use during exams week. You must select the items for your care package, pack the items for display and shipping, and calculate the cost of the care package. How can you package foods to survive the hazards of shipping and keep your costs to a minimum?

### Make a Model

- 1. Complete the safety form before you begin.
- **2. Choose** the snack items that you would like to include in your care package.
- **3. Plan** how you are going to pack your items so that they are nicely displayed and safe for shipping.
- **4. Plan** the design of your decorative wrapper and labels. Remember to make the wrapper attractive so that customers will want to purchase your product.
- **5. Design** a data table in your Science Journal to keep track of all your costs to make the care package.
- **6. Evaluate** your design plan. Determine if there are ways to cut costs to increase your profit.
- **7.** Make sure your teacher approves your plan before you start.



# Using Scientific Methods

### Test Your Model

- 1. Assemble the items that you need to carry out your plan.
- 2. Pack the materials according to your plan. Do not put on the decorative wrapper until after you have tested your package.
- 3. After you have carefully packed your box, test to make sure that everything is secure. Drop the box from the height of your lab table five times.
- 4. Unwrap your box to see if anything is damaged. If the contents are broken, determine changes that can be made to improve your design.
- 5. If needed, retest your new design. After the drop tests are successful, apply your wrapper and labels.



# Analyze Your Data

- 1. Calculate the cost of your package.
- 2. **Determine** the constraints of your design.

# Conclude and Apply

- 1. **Explain** how you can improve your design. Consider cost, contents of package, and packaging.
- 2. **Determine** under what conditions the contents of your package may be damaged. For example, if your package contains chocolate, the package cannot be shipped during hot summer months. What changes can you make to your design to remove the shipping constraints?
- 3. Infer what would happen to the contents of your package if the package were dropped from heights taller than your lab table.



Present your design to your classmates. Compare your design to those of your classmates. Look for ways that you could improve your design.

# **Accidents** in **SCIENCE**

SOMETIMES GREAT **DISCOVERIES HAPPEN BY ACCIDENT!** 

A Slippoe

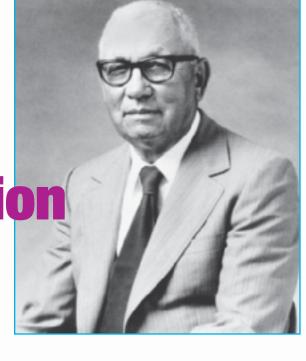
Situatio

ddly enough, one of the slipperiest substances, Teflon®, was discovered by accident. Teflon was discovered in 1938 by Roy Plunkett, a research scientist. He was trying to improve the chemicals that refrigerators use to stay cool. He experimented with dozens of chemicals. One day, he noticed a gas cylinder that wouldn't operate. When he took the cylinder apart, he found that a white, slippery powder had clogged it.

Instead of being frustrated by a glitch in his experiment, Plunkett took the time to test this strange substance. What he found was amazing. This substance turned out to be extremely resistant to heat and highly inert. A substance that is inert will not react

> with other substances.

Why is Teflon resistant to heat and corrosion? Because it is a polymer.



Polymers are compounds with long strings of a repeating unit, like a chain. This makes them very strong. This is why Teflon can withstand high temperatures and corrosion. Plastics are another example of a very strong polymer.

At first, scientists were skeptical about any practical uses for Teflon because it was so difficult to manufacture and therefore, very expensive. However, that changed when the Manhattan Project (the group of scientists who developed the atomic bomb) needed a substance that was heat resistant and chemically inert. This was the perfect job for Teflon. Since then, Teflon has found its way into many items, including the space shuttle, surgical implants, stain guards, and, of course, easy-to-clean pots and pans.

Look With a partner, walk around the room and make a list of objects that are made from polymers. The length of the list will surprise you. Your teacher can help you find many polymers.



### Reviewing Main Ideas

### **Section 1 Science and Technology**

- **1.** The study of science leads to a better understanding of the world around you.
- **2.** Scientists bring information and insight to the public's attention and provide an understanding of why an event



- occurs. The knowledge that microbes cause illness and diseases changed people's behavior. Today we take precautions to prevent the spread of microbes by washing our hands often and covering our mouth when we cough.
- **3.** Once people understand why an event or natural process occurs, they can respond and try to control the outcome.
- **4.** Technology can be an object, a method or technique for making an object or tool, the knowledge or skill needed to operate a human-made object, or a system of people or objects that perform a task.
- **5.** The value of technology varies over time and from location to location. This electric guitar may be valued by some in industrialized



nations, but people in developing countries do not have electricity in their homes. This technology would be useless to them.

### Section 2

# Forces that Shape Technology

- **1.** Funding for scientific research and technology comes from the federal government, private industries, and private foundations.
- **2.** Consumers affect which technologies will be developed by their voting and buying habits.
- **3.** Humans can have an enormous impact on other living things and must practice responsible technology.
- **4.** The consequences of technology may be known immediately, but sometimes they are not known for a period of time.
- **5.** Moral and ethical issues should be considered when doing scientific research or developing technology.

### Section 3 Developing Technology

- **1.** Scientists and engineers have different roles in developing technology.
- 2. Technological problems often create a demand for new scientific knowledge.



3. Scientists and engineers use a methodical process to develop technology. Performance testing is an important part of this process that reduces or prevents product failure.

FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review science, technology, and society.

### **Using Vocabulary**

agricultural biotechnology p. 45 computer simulation p. 55 constraints p. 55 control system p.56 engineer p.53 pilot plant p.56 prototype p.56 society p.46

Answer each question using the correct vocabulary word(s).

- **1.** Which professional in science devises a way to use scientific knowledge to solve a problem or mass-produce a product?
- **2.** What is performance-testing using a computer to imitate the process called?
- **3.** What is the name of a group of people that share similar values and beliefs?
- **4.** What is the term for design limitations put on the design by outside factors?
- **5.** What is the full-scale model that is used to performance-test a new car design called?
- **6.** What is the name of a scaled-down version of real production equipment that closely models actual manufacturing conditions?
- **7.** What is a device that monitors a system to keep it operating at preset conditions called?

### **Checking Concepts**

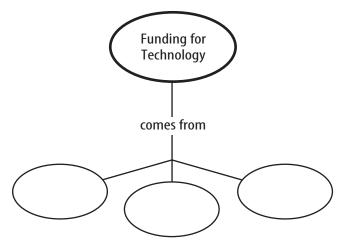
Choose the word or phrase that best answers the question.

- 8. Which represents technology?
  - A) canary
- c) eating an apple
- **B)** digital camera
- **D)** native grass
- **9.** Which technological object would be most valued in a developing country?
  - A) compact discs
  - B) electric can opener
  - c) portable water purifier
  - **D)** video recorder

- **10.** What is a collection of scientific techniques that are used to create, improve, or modify plants, animals, and microorganisms?
  - A) agricultural biotechnology
  - B) agricultural cloning
  - **c)** agricultural prototype
  - **D)** agricultural simulation
- **11.** Which is **NOT** normally a source of funding for technology?
  - **A)** federal government
  - **B)** local government
  - **c)** private foundation
  - **D)** private industry
- **12.** Which is **NOT** considered part of moral and ethical considerations?
  - A) doing what is cost effective
  - **B)** doing what is fair
  - **c)** doing what is honest
  - **D)** doing what is right
- **13.** What is the term for limitations put on the design of a product from outside factors?
  - A) conflicts
- **c)** parameters
- **B)** constraints
- **D)** specifications
- **14.** A thermostat on an air conditioner is an example of which of the following?
  - **A)** control system
  - **B)** environmental system
  - **c)** monitoring system
  - **D)** on/off system
- **15.** What are patents legal protection for?
  - **A)** new medicine
  - **B)** new novels
  - **C)** new product symbol
  - **D)** new songs
- **16.** Which does NOT represent technology?
  - A) calculator
  - B) computer program
  - **c)** granite rock
  - **D)** compact discs

### **Interpreting Graphics**

**17.** Copy and complete the following concept map on technology.



18. Make a table classifying each of the following actions as science or technology: finding the composition of Saturn's rings, developing the vehicle that can travel to Saturn, finding the human genes that cause a birth defect, and producing a medicine that can cure a disease.

### **Thinking Critically**

- 19. Draw Conclusions Explain why technology of the past, such as the protective clothing shown in Figure 1, seems ridiculous to us today even though the people of the time accepted the technology as reasonable.
- **20. Describe** one way in which scientific knowledge has changed people's understanding of a natural process or event.
- **21.** Describe each type of technology and give a new example of each type.
- **22.** Explain why the aircraft radar used by airtraffic controllers represents all types of technology.

- **23. Explain** why the value of technology may differ for people living in different parts of the world.
- **24.** List three technological items that you value that would not be important in a developing country such as Kenya.
- **25. Describe** how technology can be used to supply basic human needs for survival to those who are in need.
- **26.** Explain why ethics are important to scientists.
- **27.** Explain how citizens of a local community can influence the development of new technology.
- **28.** Explain During the mid 1970s, gasoline was in short supply. The price for gasoline increased. Automobile manufacturers produced smaller, fuel-efficient cars. The crisis soon was over and the smaller cars did not sell well. Explain how consumers' actions determined where the manufacturers spent their research funds.
- **29.** Explain What type of intellectual property is protected by copyright? How does a copyright differ from a patent?

### **Applying Math**

- **30.** Calculate A hybrid car gets 20 km/L in city driving. The same model that is gasoline-powered gets 14 km/L in city driving. If gasoline costs \$0.53 per liter, how much money would be saved per year if you drove 19,000 km of city driving?
- **31. Calculate** How many liters of gasoline would be saved using the hybrid car instead of the gasoline-powered car?

# chapter 2 Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

### **Multiple Choice**

- **1.** What did Louis Pasteur discover as the cause of infections and diseases?
  - A. bad air
  - **B.** fleas
  - c. microbes
  - **D.** rats

### Use the photo below to answer question 2.



- **2.** Which technological object would be more valuable to the family shown?
  - **A.** airline industry
  - **B.** automobile industry
  - **c.** the Internet
  - **D.** medical center

- **3.** Which is a technological system for sharing information?
  - **A.** airline industry
  - **B.** automobile industry
  - **c.** the Internet
  - **D.** medical center
- **4.** What does a society share?
  - **A.** biotechnology
  - B. consumed goods
  - **c.** new technologies
  - **D.** similar values and beliefs

### Use the photo below to answer question 5.



- **5.** Which process used by people to influence technological development is shown?
  - **A.** consumer purchase
  - **B.** federal spending
  - **c.** political discussion
  - **D.** private funding

### **Gridded Response**

- **6.** If a liter of gasoline costs \$0.58 and a car gets 11 km/L, what would it cost to travel 100 km?
- **7.** Assuming that gasoline costs the same as in the previous question, how much would it cost to travel 100 km in a car that gets 6 km/L?

### Short Response

Use photo below to answer question 8.



- **8.** Identify one positive and one negative consequence from the use of gasolinepowered cars.
- **9.** How would technological advances in health care benefit people in developing countries?

- **10.** Why were people less concerned about fuel-efficient cars in the past than they are today?
- **11.** What led to laws being created to prevent unethical treatment of animals and humans?
- **12.** How does consumer acceptance affect the development of technology?

### **Extended Response**

Use photo below to answer question 13.



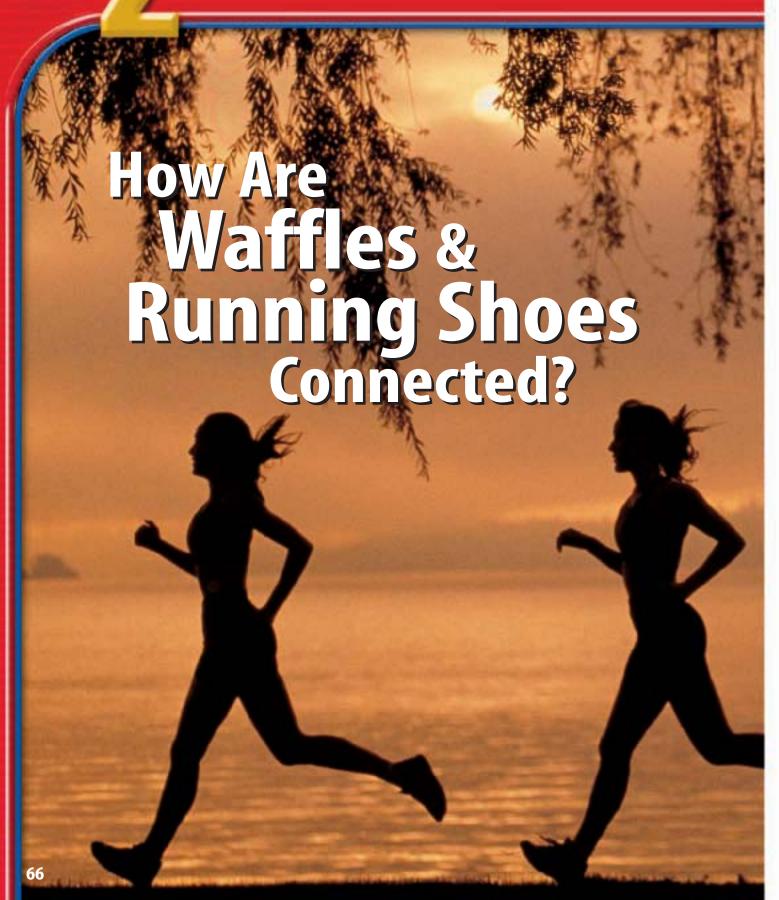
- **13. Part A** In general, how do scientists and engineers work together to find a technological solution?
  - **Part B** How would scientists and engineers determine if a new airplane design were more aerodynamic?

### **Test-Taking Tip**

Get plenty of sleep—at least 8 hours every night—during test week and the week before the test.



# Motion, Forces, and Energy





# chapter

# 3

### BIG (Idea

Motion occurs when an object changes its position.

### 3.1 Describing Motion

MAIN (Idea An object's speed depends on how far an object travels in a unit of time.

### 3.2 Acceleration

MAIN (Idea Acceleration describes how the velocity of an object is changing.

### 3.3 Motion and Forces

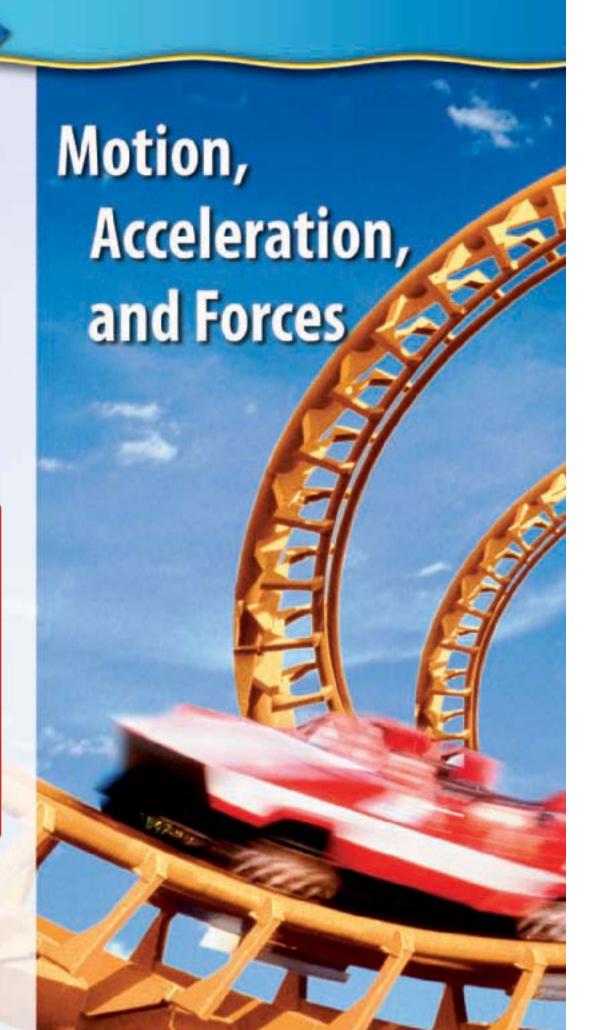
MAIN (Idea An object's motion changes only if the forces acting on the object are unbalanced.

### Taking the Plunge

How would you describe a ride on a roller coaster? You might talk about the thrills you experienced on the high-speed turns or on the breath-taking downhill plunges. The high speeds and sudden changes in speed and direction can all help make the ride a memorable experience.

### **Science Journal**

Write a paragraph describing how three different rides in an amusement park cause you to move.



# **Start-Up Activities**



### **Compare Speeds**

A cheetah can run at a speed of almost 120 km/h and is the fastest runner in the world. A horse can reach a speed of 64 km/h; and the fastest snake slithers at a speed of about 3 km/h. The speed of an object is calculated by dividing the distance the object travels by the time it takes it to move that distance. How does your speed compare to the speeds of these animals?

- 1. Complete the safety form.
- 2. Use a meterstick to mark off 10 m.
- 3. Have your partner use a stopwatch to determine how fast you run 10 m.
- **4.** Divide 10 m by your time in seconds to calculate your speed in m/s.
- 5. Multiply your answer by 3.6 to determine your speed in km/h.
- **6. Think Critically** Write a paragraph in your Science Journal comparing your speed with the maximum speed of a cheetah, horse, and snake. Could you win a race with any of them?



Preview this chapter's content and activities at gpescience.com



**Motion** Many things are in motion in your everyday life. Make the following Foldable to

help you better understand motion as you read the chapter.

STEP 1

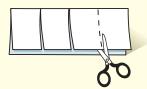
**Fold** a sheet of paper in half lengthwise. Make the back edge about 1.25 cm longer than the front edge.



Fold in half, then fold in half again to make three folds.



STEP 3 Unfold and cut only the top layer along the three folds to make four tabs.



**STEP 4** Label the tabs.



**Identify Questions** Before you read the chapter, select a motion you can observe and write it under the left tab. As you read the chapter, write answers to the other questions under the appropriate tabs.

# 1

# **Describing Motion**

### **Reading Guide**

### What You'll Learn

- Distinguish between distance and displacement.
- Calculate average speed.
- Explain the difference between speed and velocity.
- Interpret motion graphs.

# Why It's Important

Understanding the nature of motion and how to describe it helps you understand why motion occurs.

### Review Vocabulary

**instantaneous:** occurring at a particular instant of time

### **New Vocabulary**

- displacement
- vector
- speed
- instantaneous speed
- average speed
- velocity





**Figure 1** This mail truck is in motion.

**Infer** How do you know the mail truck has moved?

### **Motion**

Every day you see objects and people in motion. Cars, buses, and trucks move along streets and highways. People around you walk and run and move in different directions. How would you describe the motion of the people and objects around you? One way to describe motion is to say that it is fast or slow. However, sometimes you might need to know the speed of an object, as well as the direction in which it is moving. It also might be important to know how the motion of something is changing.

**Motion is a Change in Position** You don't always need to see something move to know that motion has taken place. For example, suppose you see a mail truck stopped next to a mailbox, as in **Figure 1.** A little while later, you see the same truck stopped farther along the street. Although you didn't see the truck move, you know it moved because its position relative to the mailbox changed. Motion occurs when an object changes position.

**Position Depends on a Reference Frame** To measure the position of an object, a reference frame must be chosen. A reference frame is a group of objects that are not moving relative to each other. One point in the reference frame is chosen as the reference point. Then the position of an object is the distance and the direction of the object from the reference point. For example, in **Figure 1** the mailbox, the tree, and the houses can form a reference frame because they aren't moving relative to each other.

**Motion is Relative** The motion of an object depends on the reference frame that is chosen. For example, suppose you are sitting in a moving car. You are not moving if the car is the reference frame, but you are moving relative to the ground. Using the Sun as a reference frame, Earth is moving at a speed of 30 km/s. However, the Sun also is moving relative to a reference frame centered on the Milky Way Galaxy. Your motion would be different in each of these reference frames. However, there is no special reference frame that really is at rest compared to all other reference frames. As a result, an object does not have absolute motion, but only motion relative to a chosen reference frame.

**Distance and Displacement** Suppose a runner jogs to the 50-m mark and then turns around and runs back to the 20-m mark, as shown in **Figure 2.** How far did the runner travel? For a moving object, distance is the length of the path the object travels. The runner traveled a distance of 50 m plus 30 m, or 80 m. However, even though she ran 80 m, she is only 20 m from the starting line. Her final position is 20 m north of her initial position. **Displacement** is the distance and direction of an object's final position from its initial position. The runner's displacement is 20 m north.

Displacement includes both a size and a direction. The size of the displacement is the distance between the initial and final position. A quantity that is specified by both a size and a direction is a vector. Displacement includes both a size and a direction and is an example of a vector. However, distance is a physical quantity that does not include a direction and isn't a vector.



How do distance and displacement differ?

### **Speed**

To describe how fast something is moving, you need to know how far it travels in a given amount of time. **Speed** is the distance an object travels per unit of time. In SI units, the unit of speed is meters per second (m/s). Usually the speed of an object changes as it moves from one place to another.

One way to describe the speed of an object is to measure its speed at a single instant of time. The **instantaneous speed** of an object is the speed at a single instant of time. A car's speedometer measures the instantaneous speed of the car.



### Measuring Average Speed

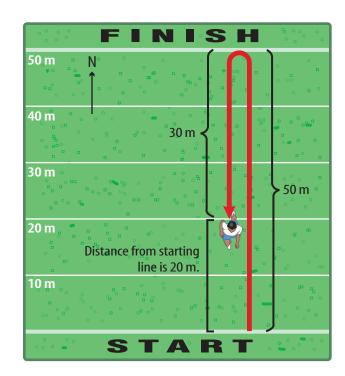
### Procedure 🗪 📶

- 1. Complete the safety form.
- 2. Mark a point on the floor with tape. Place a toy car at this point.
- **3.** Give the toy car a gentle push forward. At the same time, start a **stopwatch**.
- **4.** Record the time it takes for the car to come to a stop.
- Use a meterstick to measure the distance the car traveled.

### **Analysis**

Calculate the average speed of the car in m/s. How does the average speed depend on the direction of motion?

**Figure 2** The runner's displacement is 20 m north of the starting line. However, the total distance traveled is 80 m.





### **Topic: Running Speeds**

Visit **gpescience.com** for Web links to information about the speeds of various animals.

**Activity** Make a table comparing the top speed of various animals.

**Average Speed** Another way to describe the motion of an object is to determine the object's average speed. The average speed describes how quickly an object moved over the entire distance it traveled. The **average speed** of any object is the total distance traveled divided by the total travel time:

### **Average Speed Equation**

 $\frac{\text{average speed (in meters/second)}}{\text{total time (in seconds)}} = \frac{\text{total distance (in meters)}}{\text{total time (in seconds)}}$ 

$$\overline{v} = \frac{d}{t}$$

The units of average speed are always a distance unit divided by a time unit. Sometimes it is more convenient to express average speed in units other than m/s, such as kilometers per hour (km/h).

## **Applying Math**

### **Solve a One-Step Equation**

**AVERAGE SPEED** What is the average speed of a car that travels a distance of 750 m in 25 s?

IDENTIFY known values and the unknown value

Identify the known values:

travels a distance of 750 m d = 750 m

in 25 s means t = 25 s

Identify the unknown value:

What is the average speed?  $\overline{v} = ? \text{ m/s}$ 

SOLVE the problem

Substitute the given values of distance and time into the average speed equation:

$$\overline{v} = \frac{d}{t} = \frac{750 \,\text{m}}{25 \,\text{s}} = 30 \,\text{m/s}$$

**CHECK** your answer:

Does your answer seem reasonable? Check your answer by multiplying the time by the average speed. The result should be the distance given in the problem.

### **Practice Problems**

- **1.** An elevator travels a distance of 220 m from the first floor to the 60th floor in 27.5 s. What is the elevator's average speed?
- **2.** A motorcyclist travels with an average speed of 20 km/h. If the cyclist is going to a friend's house 5 km away, how long does it take the cyclist to make the trip?

For more practice problems, go to page 879 and visit Math Practice at gpescience.com.

# **Velocity**

You turn on the TV and see a news story about a hurricane, such as the one in Figure 3, that is approaching land with a speed of 10 km/h. The eye of the hurricane is located 450 km east of your location. Should you take shelter?

If you know only the hurricane's speed and location, you don't have enough information to answer the question. To decide whether the hurricane will reach your location, you need to know the direction in which the storm is moving. In other words, you need to know the velocity of the hurricane. The velocity of an

object is the speed of the object and its direction of motion. Just like displacement, velocity is a vector that has a size and a direction. The size of an object's velocity is the object's speed.

Objects have different velocities if they are moving at different speeds, or in different directions. The people on the up escalator and the down escalator in Figure 4 are moving with the same speed, but in opposite directions. As a result, the people on the up escalator and the down escalator have a different velocity.

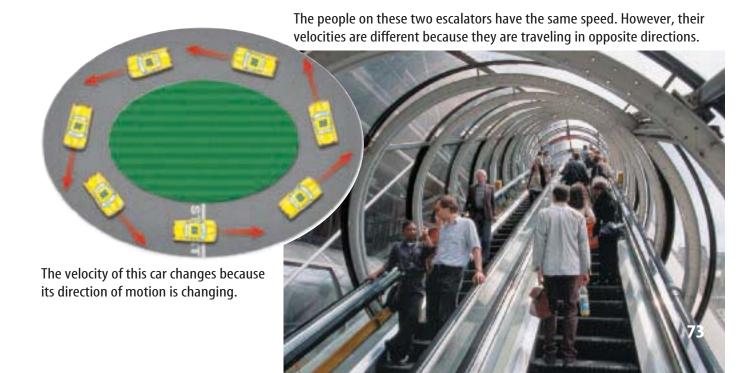
The velocity of an object can change even if the speed of the object remains constant. For example, look at **Figure 4.** The race car has a constant speed as it goes around an oval track. Even though the speed remains constant, the velocity changes because the direction of the car's motion is changing.

Reading Check How are velocity and speed different?

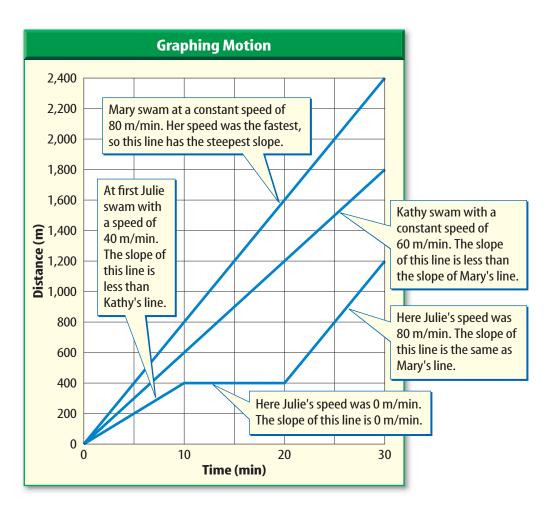


**Figure 3** The speed of a hurricane is not enough information to plot the hurricane's path. The direction of its motion also must be known.

**Figure 4** The velocity of an object depends on both its speed and its direction of motion. **Describe** how the car's velocity changes as the car travels from the starting line to the top of the figure.



**Figure 5** The slope of a line on a distance-time graph gives the speed of an object in motion. **Identify** the part of the graph that shows one of the swimmers resting for 10 min.



# Astronomy

Orbital Speeds Size, mass, composition, and orbital radius are some of the ways astronomers classify planets. Astronomers also measure the speed of a planet relative to the Sun. Make a table of the average orbital speeds and orbital radii of the nine planets in the solar system. How are distance from the Sun and orbital speed related?

# **Graphing Motion**

The motion of an object over a period of time can be shown on a distance-time graph. Time is plotted along the horizontal axis of the graph and the distance traveled is plotted along the vertical axis of the graph. If the object moves with constant speed, the increase in distance over equal time intervals is the same. As a result, the line representing the object's motion is a straight line.

For example, the graph shown in **Figure 5** represents the motion of three swimmers during a 30-min workout. The straight red line represents the motion of Mary, who swam with a constant speed of 80 m/min over the 30-min workout. The straight blue line represents the motion of Kathy, who swam with a constant speed of 60 m/min during the workout.

The graph shows that the line representing the motion of the faster swimmer is steeper. The steepness of a line on a graph is the slope of the line. The slope of a line on a distance-time graph equals the speed. A horizontal line on a distance-time graph has zero slope, and represents an object at rest. Because Mary has a larger speed than Kathy, the line representing her motion has a larger slope.

**Changing Speed** The green line represents the motion of Julie, who did not swim at a constant speed. She covered 400 m at a constant speed during the first 10 min, rested for the next 10 min, and then covered 800 m during the final 10 min. During the first 10 min, her speed was less than Mary's or Kathy's, so her line has a smaller slope. During the middle period her speed is zero, so her line over this interval is horizontal and has zero slope. During the last time interval she swam as fast as Mary, so that part of her line has the same slope.

Plotting a Distance-Time Graph On a distance-time graph, the distance is plotted on the vertical axis and the time on the horizontal axis. Each axis must have a scale that covers the range of numbers to be plotted. In **Figure 5** the distance scale must range from 0 to 2,400 m and the time scale must range from 0 to 30 min. Then, each axis can be divided into equal time intervals to represent the data. Once the scales for each axis are in place, the data points can be plotted. After plotting the data points, draw a line connecting the points.



# Topic: Olympic Swimming Speeds

Visit **gpescience.com** for Web links to information about the speeds of Olympic swimmers over the past 60 years.

**Activity** Make a speed-year graph showing the swimming speeds over time. Are there any trends in the speed data?

### section

## review

### Summary

#### **Position and Motion**

- The position of an object is determined relative to a reference point.
- Motion occurs when an object changes its position relative to a reference point.
- Distance is the length of the path an object has traveled. Displacement is the distance and direction of a change in position.

#### **Average Speed and Velocity**

 Average speed is the total distance traveled divided by the total time:

$$\overline{v} = \frac{d}{t}$$

 The velocity of an object includes the object's speed and its direction of motion relative to a reference point.

#### **Graphing Motion**

- On a distance-time graph, time is the horizontal axis and distance is the vertical axis.
- The slope of a line plotted on a distance-time graph is the speed.

#### **Self Check**

- Infer whether the size of an object's displacement could be greater than the distance the object travels.
- **2. Describe** the motion represented by a horizontal line on a distance-time graph.
- **3. Explain** whether, during a trip, a car's instantaneous speed can ever be greater than its average speed.
- **4. Describe** the difference between average speed and constant speed.
- 5. Think Critically You are walking toward the back of a bus that is moving forward with a constant velocity. Describe your motion relative to the bus and relative to a point on the ground.

### **Applying Math**

- **6. Calculate Average Speed** Michiko walked a distance of 1.60 km in 30 min. Find her average speed in m/s.
- **7. Calculate Distance** A car travels at an average speed of 30.0 m/s for 0.8 h. Find the total distance traveled in km.

# **Acceleration**

### **Reading Guide**

### What You'll Learn

- Identify how acceleration, time, and velocity are related.
- Describe how to calculate the average acceleration of an object.
- **Explain** how positive and negative acceleration affect motion.

# Why It's Important

Acceleration occurs all around you as objects speed up, slow down, or change direction.

### Review Vocabulary

velocity: a vector with a size that is an object's speed and a direction that is the direction of an object's motion

### **New Vocabulary**

acceleration

# **Acceleration, Speed, and Velocity**

A car at a stoplight starts moving when the light finally turns green. When the car started moving, the car's velocity increased and the car was accelerating. Acceleration is the change in velocity divided by the time for the change to occur.

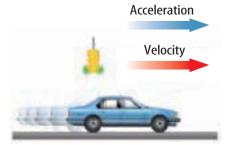
Remember that velocity is a vector that includes both the speed and direction of motion. So a change in velocity can either be a change in speed or a change in direction of motion. Acceleration occurs when the speed of an object changes or its direction of motion changes.

### Reading Check When does acceleration occur?

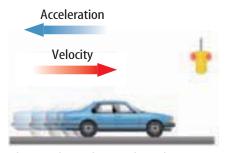
Just as velocity has a size and direction, acceleration also is a vector that has a size and direction. **Figure 6** shows how acceleration can cause an object to speed up or slow down.

**Figure 6** These cars are both accelerating because their speed is changing.

**Infer** how the car would move if its acceleration were zero.



The car speeds up when the acceleration and velocity are in the same direction.



The car slows down when the acceleration and velocity are in opposite directions.

**Changing Direction** A change in velocity can be either a change in how fast something is moving or a change in the direction of movement. Any time a moving object changes direction, its velocity changes and it is accelerating. Think about a horse on a carousel. Although the horse's speed remains constant, the horse is accelerating because it is changing direction constantly as it travels in a circular path, as shown in **Figure 7.** Another example is the motion of Earth around the Sun in a nearly circular path. As a result, the direction of Earth's velocity is continually changing. This means that Earth is accelerating as it orbits the Sun.

# **Calculating Acceleration**

When an object moves from one place to another, it might speed up, slow down, and change direction many times. Each change in velocity causes the acceleration of the object to change. When acceleration is changing, the size of the average acceleration over some period of time can be calculated. If the direction of motion of an object doesn't change, the size of its average acceleration can be calculated using the following equation:

Acceleration Equation

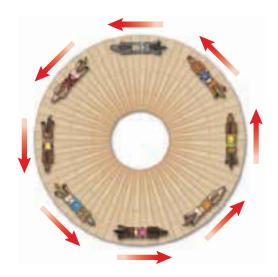
average acceleration (in m/s<sup>2</sup>) =

$$\frac{(\text{final velocity (in m/s)} - \text{initial velocity (in m/s))}}{(\text{final time (s)} - \text{initial time (s))}}$$

$$\bar{a} = \frac{(v_{\text{f}} - v_{\text{i}})}{(t_{\text{f}} - t_{\text{i}})}$$

In this equation,  $v_i$  is the size of the velocity at the start of the time period and  $v_f$  is the size of the velocity at the end of the time period. For motion in a single direction,  $v_i$  is the same as the initial speed, and  $v_f$  is the same as the final speed. In SI units, acceleration has units of m/s<sup>2</sup>—meters per second squared. An acceleration of 1 m/s<sup>2</sup> means that the velocity of the object increases by 1 m/s each second. If the object was initially at rest, its velocity would be 1 m/s after 1 s, 2 m/s after 2 s, and so on.

**Speed-Time Graphs** For an object moving in one direction, the acceleration can be found from a speed-time graph. For this type of graph, the vertical axis is the object's speed and the horizontal axis is the time. Then the slope of the plotted line is the size of the object's acceleration. **Figure 8** shows some examples of speed-time graphs.



**Figure 7** The speed of each horse on this carousel is constant but each is accelerating because the direction of its velocity is changing.



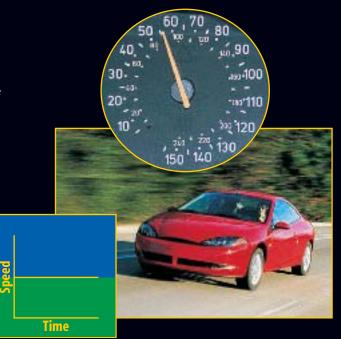
Aircraft Carriers In 1911, American pilot Eugene Ely successfully landed on a specially equipped deck on the battleship Pennsylvania. Today, huge aircraft carriers provide floating landing strips for military airplanes. Carriers must be equipped to provide large accelerations, both positive and negative, to the jets launched from their decks. Research the accelerations provided by modern carriers as they launch and land aircraft.

# NATIONAL GEOGRAPHIC VISUALIZING ACCELERATION

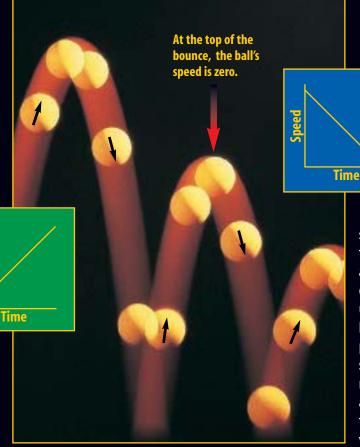
### Figure 8

cceleration can be positive, negative, or zero depending on whether an object is speeding up, slowing down, or moving at a constant speed. If the speed of an object is plotted on a graph, with time along the horizontal axis, the slope of the line is related to the acceleration.

A The car in the photograph on the right is maintaining a constant speed of about 90 km/h. Because the speed is constant, the car's acceleration is zero. A graph of the car's speed with time is a horizontal line.



B The green graph shows how the speed of a bouncing ball changes with time as it falls from the top of a bounce. The ball speeds up as gravity pulls the ball downward, so the acceleration is positive. For positive acceleration, the plotted line slopes upward to the right.



The blue graph shows the change with time in the speed of a ball after it hits the ground and bounces upward. The climbing ball slows as gravity pulls it downward, so the acceleration is negative. For negative acceleration, the plotted line slopes downward to the right.

**Calculating Positive Acceleration** How is the acceleration for an object that is speeding up different from that of an object that is slowing down? Suppose the jet airliner in **Figure 9** starts at rest and moves down the runway in a single direction. After accelerating for 20 s, it reaches a speed of 80 m/s. Because it started from rest, its initial speed was zero. The jetliner's average acceleration can be calculated as follows:

$$\bar{a} = \frac{(v_f - v_i)}{(t_f - t_i)} = \frac{(80 \text{ m/s} - 0 \text{ m/s})}{20 \text{ s}} = 4 \text{ m/s}^2$$

The airliner is speeding up, so the final speed is greater than the initial speed and the acceleration is a positive number.

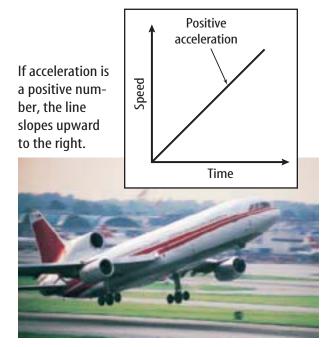
**Calculating Negative Acceleration** Now imagine that the skateboarder in **Figure 9** is moving in a straight line at a constant speed of 3 m/s and comes to a stop in 2 s. The final speed is zero and the initial speed was 3 m/s. The skateboarder's acceleration is calculated as follows:

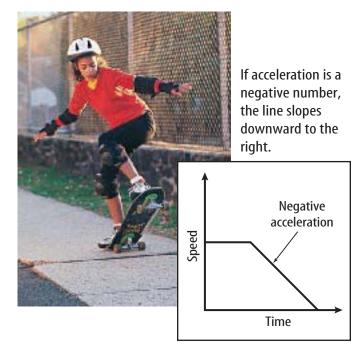
$$\overline{a} = \frac{(v_f - v_i)}{(t_f - t_i)} = \frac{(0 \text{ m/s} - 3 \text{ m/s})}{2 \text{ s}} = -1.5 \text{ m/s}^2$$

The skateboarder is slowing down, so the final speed is less than the initial speed and the acceleration is a negative number. For an object moving in one direction, the acceleration will be a positive number if an object is speeding up and a negative number if the object is slowing down.

**Figure 9** A speed-time graph tells you if acceleration is a positive or negative number.

**Infer** what a steeper slope indicates on a speed-time graph.







**Figure 10** Cars on this roller coaster can reach a speed of about 150 km/h in 4 s.

### **Amusement Park Acceleration**

Riding roller coasters in amusement parks can give you the feeling of danger, but these rides are designed to be safe. Engineers use the laws of physics to design amusement park rides that are thrilling, but harmless. Roller coasters are constructed of steel or wood. Because wood is not as rigid as steel, wooden roller coasters do not have hills that are as high and steep as some steel roller coasters have. As a result, the highest speeds and accelerations usually are produced on steel roller coasters.

Steel roller coasters can offer multiple steep drops and inversion loops, which give the rider large accelerations. As the rider moves down a steep hill or an inversion loop, he or she will accelerate toward the ground due to gravity. When riders go around a sharp turn, they also are accelerated. This acceleration makes them feel as if a force is pushing them toward the side of the car. **Figure 10** shows the fastest roller coaster in the United States.



What happens when riders on a roller coaster go around a sharp turn?

### section

# review

### Summary

### **Acceleration, Speed, and Velocity**

- Acceleration is the change in velocity divided by the time needed for the change to occur.
- A change in velocity occurs when an object changes its speed or direction of motion.
- The speed of an object increases if the acceleration is in the same direction as the velocity.
- The speed of an object decreases if the acceleration and the velocity of the object are in opposite directions.

### **Calculating Acceleration**

 The average acceleration of an object can be calculated using this equation:

$$\overline{a} = \frac{(v_{\rm f} - v_{\rm i})}{(t_{\rm f} - t_{\rm i})}$$

- When an object moving in a straight line speeds up, its acceleration is positive
- When an object moving in a straight line slows down, its acceleration is negative.

### **Self Check**

- **1. Determine** whether you are accelerating as Earth rotates once every 24 h.
- **2. Determine** the change in velocity of a car that starts at rest and has a final velocity of 20 m/s north.
- Explain why streets and highways have speed limits rather than velocity limits.
- **4. Describe** the motion of an object that has an acceleration of 0 m/s<sup>2</sup>.
- **5. Think Critically** Suppose a car is accelerating so that its speed is increasing. Describe the plotted line of the motion of the car on a distance-time graph.

### **Applying Math**

- **6. Calculate Acceleration** A ball is dropped from a cliff and reaches a speed of 29.4 m/s after 3.0 s. What is the ball's average acceleration?
- **7. Calculate Speed** A sprinter runs with an average acceleration of 4.5 m/s<sup>2</sup>. What is the sprinter's speed 2 s after leaving the starting blocks?

# **Motion and Forces**

## **Reading Guide**

### What You'll Learn

- Explain how forces and motion are related.
- Compare and contrast static friction and sliding friction.
- **Describe** the effects of air resistance on falling objects.

# Why It's Important

All changes in motion are caused by the forces that act on objects.

### Review Vocabulary

vector: a quantity that includes both a size and a direction

### **New Vocabulary**

- force
- net force
- balanced forces
- unbalanced forces
- friction
- static friction
- sliding friction
- air resistance

### What is force?

When you shoot a basketball or kick a soccer ball, you are exerting a force on an object. In fact, every push or pull you exert results in a force being applied to some object. A force is a push or pull that one object exerts on another. Just like velocity and acceleration, force also is a vector that has a size and a direction. The size of a force often is called the strength of the force. The direction of a force is the direction in which the push or pull is applied. For example, when you lift your backpack, you apply an upward force. In SI units, force is measured in newtons (N). You have to apply a force of about 3 N to lift a full can of soft drink.

Figure 11 This ball is hit with a force. The racket strikes the ball with a force in the opposite direction of its motion. As a result, the ball changes the direction it is moving.

**Changing Motion** What happens to the motion of an object when you exert a force on it? A force can cause the motion of an object to change, as in **Figure 11.** The racket strikes the ball with a force that causes the ball to stop and then move in the opposite direction. If you have played billiards, you know that you can cause a ball at rest to roll into a pocket by striking it with another ball. The force applied by the moving ball causes the ball at rest to move in the direction of the force. In these cases, the velocities of the tennis ball and the billiard ball were changed by a force.



Figure 12 Forces can be balanced and unbalanced.



A These students are pushing on the box with an equal force but in opposite directions. Because the forces are balanced, the box does not move.

Net Force = 0



B These students are pushing on the box with unequal forces in opposite directions. The box will be moved in the direction of the larger force.

Net Force =



These students are pushing on the box in the same direction. The combined forces will cause the box to move.

Net Force =



### **Topic: Forces and Fault** Lines

Visit **gpescience.com** for Web links to information about the unbalanced forces that occur along Earth's fault lines.

**Activity** Use inexpensive materials such as bars of soap to model the forces and movements along the fault lines. Share your models and demonstrations with your class.

**Balanced Forces** Force does not always change velocity. In **Figure 12A,** two students are pushing on opposite sides of a box. Both students are pushing with an equal force but in opposite directions. When two or more forces act on an object at the same time, the forces combine to form the **net force**. The net force on the box in Figure 12A is zero because the two forces cancel each other. Forces on an object that are equal in size and opposite in direction are called balanced forces.

**Unbalanced Forces** Another example of how forces combine is shown in Figure 12B. When two students are pushing with unequal forces in opposite directions, a net force occurs in the direction of the larger force. When forces combine to produce a net force that is not zero, the forces acting on the object are **unbalanced forces.** The net force that causes the box to accelerate will be the difference between the two forces because they are in opposite directions.

In **Figure 12C**, the students are pushing on the box in the same direction. These forces are combined, or added together, because they are exerted on the box in the same direction. The net force that acts on this box is found by adding the two forces together.



Reading Check Give another example of an unbalanced force.

**Unbalanced Forces Change Velocity** When the forces acting on an object are balanced, the velocity of an object doesn't change. If you and a friend push on a door from opposite sides with the same size force, the door doesn't move. The net force is zero and the forces are balanced. But if you push harder, the door moves in the direction of your push. The velocity the door, or any object, changes only when the forces on it are unbalanced.

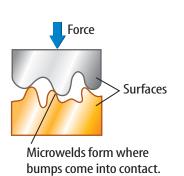
### **Friction**

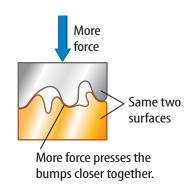
Suppose you give a skateboard a push with your hand. The skateboard speeds up as you push it and then keeps moving after it leaves your hand. What happens to the skateboard's speed if it is moving on a flat, level surface? You know the answer. The skateboard slows down and finally stops.

After it left your hand, the skateboard's velocity changed because the forces acting on it were unbalanced. The unbalanced force that slowed the skateboard was friction. Friction is the force that opposes the sliding motion of two surfaces that are in contact.

What causes friction? The size of the frictional force exerted by one surface on another depends on the materials the surfaces are made from and the roughness of the surfaces. All surfaces have bumps and dips, including highly-polished metal surfaces that seem very smooth. When two surfaces are in contact, sticking occurs where the bumps and dips touch each other. This causes microwelds to form between the two surface. These microwelds tend to make the surfaces stick together and cause friction to occur.

The frictional force between two surfaces increases when the force pushing the surfaces together increases, as shown in Figure 13. When the surfaces are pushed together with more force, more of the bumps and dips come into contact. This increases the strength of the microwelds.







### **Comparing Friction**

### 

- 1. Complete the safety form.
- 2. Place an ice cube, a rock, an eraser, a wood block, and a square of aluminum foil at one end of a metal or plastic tray.
- 3. Slowly lift the end of the tray with the items.
- 4. Have a partner use a metric ruler to measure the height of the raised end of the tray at which each object begins to slide. Record your measurements.

### **Analysis**

- 1. List the height at which each object began to slide.
- 2. How did the height at which objects began to slide depend on the roughness of the objects?
- 3. How did the forces due to static and sliding friction compare for each object?

**Figure 13** Friction is due to the microwelds that form between two surfaces in contact. These microwelds become stronger when the force pushing the surfaces together increases.

**Explain** how the area of contact between the surfaces changes when they are pushed together with a larger force.



**Figure 14** The static friction force balances the applied force so the box doesn't move. **Infer** the net force on the box.

**Static Friction** Suppose you push on a heavy box, like the one in Figure 14, and it doesn't budge. The velocity of the box didn't change, so another force is acting on the box that balances your push. This force is a frictional force called static friction that is due to the microwelds that have formed between the box and the floor. **Static friction** is the frictional force that prevents two surfaces in contact from sliding past each other. In this case, the box didn't move because your push is not large enough to break the microwelds between the two surfaces.

**Sliding Friction** You and a friend push together on the box and the box slides along the floor, as shown in **Figure 15.** As the box slides on the floor, another frictional force—sliding friction—opposes the motion of the box. Sliding friction is the force that acts in the opposite direction to the motion of a surface sliding on another surface. If you stop pushing, sliding friction causes the box to slow down and stop. The force due to sliding friction between two surfaces is smaller than the force due to static friction.



**Rolling Friction** When an object rolls over a surface, a frictional force due to rolling friction slows the object down. Rolling friction usually is much less than sliding friction. This is why it is easier to move a heavy object if it is on wheels.



**Figure 15** Sliding friction acts on the sliding box in the direction opposite to the motion of the box.

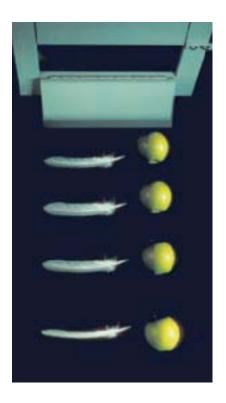
### **Air Resistance**

When an object falls toward Earth, it is pulled downward by the force due to gravity. However, a type of frictional force called air resistance opposes the motion of objects that move through the air. Air resistance causes objects to fall with different accelerations and different speeds. If there were no air resistance, then all objects, like the apple and feather shown in **Figure 16**, would fall with the same acceleration.

Air resistance acts in the direction opposite to the velocity of an object moving in air. If an object is falling downward, air resistance acts upward on the object. The size of the air resistance force depends on the size and shape of an object. Imagine dropping two identical plastic bags. One is crumpled into a ball and the other is spread out. When the bags are dropped, the crumpled bag falls faster than the spread-out bag. The downward force of gravity on both bags is the same, but the upward force of air resistance on the crumpled bag is less. As a result, the net downward force on the crumpled bag is greater, as shown in **Figure 17.** 

The amount of air resistance on an object depends on the speed, size, and shape of the object. Air resistance, not the object's mass, is why feathers, leaves, and sheets of paper fall more slowly than pennies, acorns, and apples.





**Figure 16** This photograph shows an apple and a feather falling in a vacuum. The photograph was taken with a strobe light that flashes on and off at a steady rate. Because there is no air resistance in a vacuum, the feather and the apple fall with the same acceleration.

**Figure 17** Because the bag on the left has a greater surface area, the bag on the left has more air resistance acting on it as it falls.



**Figure 18** When the sky diver reaches terminal velocity, the force due to air resistance balances the force due to gravity.

**Terminal Velocity** As an object falls, the downward force of gravity causes the object to accelerate. For example, after falling 2,000 m, without the effects of air resistance a skydiver's speed would be almost 200 m/s, or more than 700 km/h.

However, as the speed of a falling object increases, the upward force of air resistance also increases. This causes the net force on a sky diver to decrease as the sky diver falls. Finally, the upward air resistance force becomes large enough to balance the downward force of gravity. The net force on the object is zero, and the velocity of the object doesn't change. The object falls with a constant velocity called the terminal velocity. The terminal velocity is the highest velocity the falling object will reach.

The terminal velocity depends on the size, shape, and mass of the falling object. The air resistance force on an open parachute, like the one in Figure 18, is much larger than the air resistance on the a sky diver with a closed parachute. With the parachute open, the terminal velocity of the sky diver becomes small enough that the sky diver can land safely.

# section

# review

# **Summary**

#### **Balanced and Unbalanced Forces**

- A force is a push or a pull that one object exerts on another object.
- The net force on an object is the combination of all the forces acting on the object.
- When the net force on an object is zero, the forces acting on the object are balanced.
- When the net force on an object is not zero, the forces acting on the object are unbalanced.
- Unbalanced forces cause the velocity of an object to change.

#### **Friction**

- Friction is the force that opposes motion between two surfaces that are touching each other.
- Friction depends on the types of surfaces and the force pressing the surfaces together.
- Static friction prevents surfaces that are in contact from sliding past each other.

#### **Air Resistance**

 Air resistance is a force that acts on objects that move through the air.

#### **Self Check**

- **1. Explain** why the frictional force between two surfaces increases when the force pushing the surfaces together increases.
- **2. Compare** the force of air resistance and the force of gravity on an object falling at its terminal velocity.
- 3. Compare the size of forces due to static, sliding, and rolling friction between two surfaces.
- **4. Think Critically** What is the net force on a car stopped at a stop sign? What is the net force on a car moving in a straight line with a constant speed?

# Applying Math

- **5. Calculate Net Force** Two students push on a box in the same direction, and another pushes on the box in the opposite direction. What is the net force on the box if each pushes with a force of 50 N?
- **6. Calculate Sliding Friction** You push a box with a force of 80 N. If the net force on the box is 50 N, what is the force on the box due to sliding friction?
- **7. Calculate Acceleration** The downward force of gravity and the upward force of air resistance on a falling ball are both 5 N. What is the ball's acceleration?



# FOFEE AND ACCELERATION

If you stand at a stoplight, you will see cars stopping for red lights and then taking off when the light turns green. What makes the cars slow down? What makes them speed up? How do balanced and unbalanced forces affect the acceleration of objects?



How does an unbalanced force affect the motion of an object?

#### Goals

- **Observe** how changing the net force on an object affects its acceleration.
- Interpret data collected for several trials.

## **Materials**

this science book tape paper clip triple-beam balance 10-N spring scale \*electronic balance large book \*Alternate materials

# Safety Precautions 🗫 📠 🕽



Proper eye protection should be worn at all times while performing this lab.

# Procedure

- 1. Complete the safety form.
- 2. Tie the string around the book and attach the paper clip to the string.
- 3. Prepare a data table with the following headings: Force, Mass.
- **4.** If available, use a large balance to find the mass of the two books.
- 5. Place the book on the floor or on the surface of a long table. Use the paper clip to hook the spring scale to the book.



- 6. Pull the book across the floor or table at a slow but constant velocity. While pulling, read the force measured by the spring scale and record it in your data table.
- 7. Repeat step 5 two more times, once accelerating slowly and once accelerating quickly. Be careful not to pull too hard. Your spring scale will read only up to 10 N.
- **8.** Place a second book on top of the first book and repeat steps 3 through 6.

# Conclude and Apply

- 1. Organize the pulling forces from greatest to least for each set of trials. What is the relationship between the net force and the acceleration of the book?
- 2. Explain how adding the second book changed your results.



Compare your conclusions with those of other students in your class.



# **Design Your Own**

# Comparing Motion from Different Forces

#### Goals

- Identify several forces that you can use to propel a small toy car across the floor.
- Demonstrate the motion of the toy car using each of the forces.
- Graph the position versus time for each force.
- Compare the motion of the toy car resulting from each force.

#### **Possible Materials**

small toy car ramps or boards of different lengths springs or rubber bands string stopwatch meterstick or tape measure graph paper

# **Safety Precautions**



# Real-World Problem

Think about a small ball. How many ways could you exert a force on the ball to make it move? You could throw it, kick it, roll it down a ramp, blow it with a large fan, etc. Do you think the distance and speed of the ball's motion will be the same for all of these forces? Do you think the acceleration of the ball would be the same for all of these types of forces?

# Form a Hypothesis

Based on your reading and observations, state a hypothesis about how a force can be applied that will cause a toy car to go fastest.

# 🧶 Test Your Hypothesis

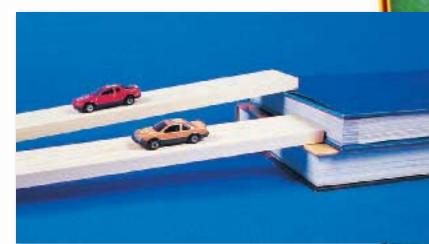
#### Make a Plan

- 1. Complete the safety form.
- **2.** As a group, agree upon the hypothesis and decide how you will test it. Identify which results will confirm your hypothesis.
- **3. List** the steps you will need to test your hypothesis. Be sure to include a control run. Be specific. Describe exactly what you will do in each step. List your materials.
- **4. Prepare** a data table in your Science Journal to record your observations.



# Using Scientific Methods

- **5. Read** the entire experiment to make sure all steps are in logical order and will lead to a useful conclusion.
- 6. Identify all constants, variables, and controls of the experiment. Keep in mind that you will need to have measurements at multiple points. These points are needed to graph your results. You should make sure to have several data points taken after you stop applying the force and before the car starts to slow down. It might be useful to have several students taking measurements, making each responsible for one or two points.



#### **Follow Your Plan**

- 1. Make sure your teacher approves your plan before you start.
- **2.** Carry out the experiment as planned.
- **3.** While doing the experiment, record your observations and complete the data tables in your Science Journal.

# Analyze Your Data

- **1. Graph** the position of the car versus time for each of the forces you applied. How can you use the graphs to compare the speeds of the toy car?
- **2. Calculate** the speed of the toy car over the same time interval for each of the forces that you applied. How do the speeds compare?

# Conclude and Apply

- **1. Evaluate** Did the speed of the toy car vary depending upon the force applied to it?
- **2. Determine** For any particular force, did the speed of the toy car change over time? If so, how did the speed change? Describe how you can use your graphs to answer these questions.
- **3. Draw Conclusions** Did your results support your hypothesis? Why or why not?



**Compare** your data with those of other students. **Discuss** how the forces you applied might be different from those others applied and how that affected your results.

# Science Language 115

# "A Brave and Startling Truth"

by Maya Angelou

We, this people, on a small and lonely planet
Traveling through casual space
Past aloof stars, across the way of indifferent suns
To a destination where all signs tell us
It is possible and imperative that we learn
A brave and startling truth ...

When we come to it
Then we will confess that not the Pyramids
With their stones set in mysterious perfection ...
Not the Grand Canyon
Kindled into delicious color
By Western sunsets

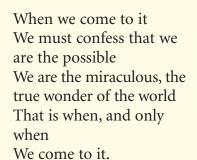
When we come to it We, this people, on this minuscule and kithless<sup>1</sup> globe ...

These are not the only wonders of the world ...

We this people on this mote<sup>2</sup> of matter

When we come to it
We, this people, on this wayward<sup>3</sup>, floating body
Created on this earth, of this earth
Have the power to fashion for this earth
A climate where every man and every woman
Can live freely without sanctimonious piety<sup>4</sup>

Without crippling fear





# **Understanding Literature**

**Descriptive Writing** The poet names some special places on Earth. These places, although marvelous, fall short of being really wonderful. How does Angelou contrast Earth's position within the universe to emphasize the importance of people?

# Respond to the Reading

- 1. What adjectives does the poet use to describe Earth?
- **2.** What does the poet believe are the true wonders of the world?
- **3. Linking Science and Writing** Write a six-line poem that describes Earth's movement from the point of view of the Moon.



Sometimes a person doesn't need to see

movement to know that something has moved. Even though we don't necessarily see Earth's movement, we know Earth moves relative to a reference point such as the Sun. If the Sun is the reference point, Earth moves because the Sun appears to change its position in the sky. The poem describes Earth's movement from a reference point outside of Earth, somewhere in space.

- 1 to be without friends or neighbors
- 2 small particle
- 3 wanting one's own way in spite of the advice or wishes of another
- 4 a self-important show of being religious

# Reviewing Main Ideas

# Section 1 Describing Motion

1. Motion is a change of position of a body. Distance is the measure of how far an object moved.

Displacement is the distance and



direction of an object's change in position from the starting point.

- **2.** A reference point must be specified in order to determine an object's position.
- **3.** The average speed of an object can be calculated from this equation:

$$\overline{v} = \frac{d}{t}$$

- **4.** Velocity is a vector that includes the speed and direction of a moving object.
- **5.** The slope of a line on a distance-time graph is equal to the speed.

# **Section 2 Acceleration**

- Acceleration occurs when an object changes speed or changes direction.
- **2.** An object speeds up if its acceleration is in the direction of its motion.



- **3.** An object slows down if its acceleration is opposite to the direction of its motion.
- **4.** Acceleration is the rate of change of velocity, and is calculated from this equation:

$$\overline{a} = \frac{v_{\rm f} - v_{\rm i}}{(t_{\rm f} - t_{\rm i})}$$

# **Section 3 Motion and Forces**

- **1.** A force is a push or a pull.
- **2.** The net force acting on an object is the combination of all the forces acting on the object.
- **3.** The forces on an object are balanced if the net force is zero.
- **4.** Sliding friction is a force opposing the sliding motion of two surfaces in contact. Static friction prevents surfaces in contact from sliding past each other.
- **5.** Air resistance opposes the motion of objects that move in the air.



FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review motion.

# **Using Vocabulary**

acceleration p.76 net force p.82
air resistance p.85 sliding friction p.84
average speed p.72 speed p.71
balanced forces p.82 static friction p.84
displacement p.71 unbalanced forces p.82
force p.81 vector p.71
friction p.83 velocity p.72
instantaneous speed p.71

Compare and contrast the following pairs of vocabulary words.

- 1. speed—velocity
- 2. distance—displacement
- 3. average speed—instantaneous speed
- 4. balanced force—net force
- 5. acceleration—velocity
- 6. velocity—instantaneous speed
- 7. static friction—sliding friction
- **8.** friction—air resistance

# **Checking Concepts**

Choose the word or phrase that best answers the question.

- **9.** Which of the following do you calculate when you divide the total distance traveled by the total travel time?
  - A) average speed
  - **B)** constant speed
  - c) variable speed
  - **D)** instantaneous speed
- **10.** Which term below best describes the forces on an object with a net force of zero?
  - A) inertia
  - **B)** balanced forces
  - **c)** acceleration
  - **D)** unbalanced forces

- **11.** Which of the following is a proper unit of acceleration?
  - A)  $s/km^2$
- C)  $m/s^2$
- B) km/h
- D) cm/s
- **12.** Which of the following is not used in calculating acceleration?
  - **A)** initial velocity
- **c)** time interval
- **B)** average speed
- **D)** final velocity
- **13.** In which of the following conditions does the car NOT accelerate?
  - **A)** A car moves at 80 km/h on a flat, straight highway.
  - **B)** The car slows from 80 km/h to 35 km/h.
  - **C)** The car turns a corner.
  - **D)** The car speeds up from 35 km/h to 80 km/h.
- **14.** What is the slope of a line on a distance-time graph?
  - A) displacement
- **c)** speed
- **B)** force
- **D)** acceleration
- **15.** How can speed be defined?
  - A) acceleration/time
  - **B)** change in velocity/time
  - c) distance/time
  - **D)** displacement/time

# **Interpreting Graphics**

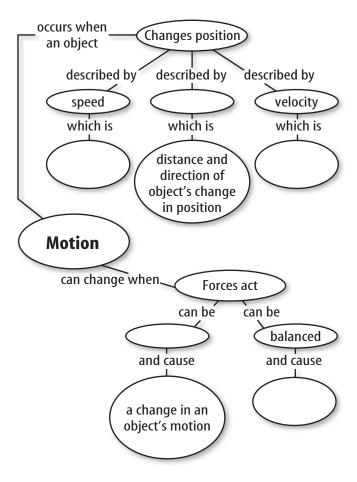
Use the table below to answer question 16.

Distance-Time for Runners				
Time (s)	1	2	3	4
Sally's distance (m)	2	4	6	8
Alonzo's distance (m)	1	2	2	4

**16. Graph** the motion of both runners on a distance-time graph. What is the average speed of each runner? Which runner stops briefly? Over what time interval do they both have the same speed?

# chapter 3 Review

**17.** Copy and complete this concept map on motion.



# **Thinking Critically**

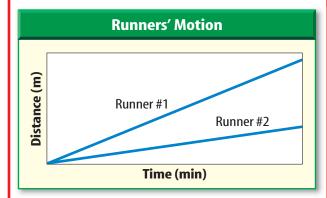
- **18. Evaluate** Which of the following represents the greatest speed: 20 m/s, 200 cm/s, or 0.2 km/s?
- **19. Describe** a line on a distance-time graph representing an object that is not moving.
- **20. Infer** You push a book on a table so that its velocity is constant. If the force you apply is 15 N, what is the force due to sliding friction?
- **21. Determine** If you walked 20 m, took a book from a library table, turned around and walked back to your seat, what are the distance traveled and displacement?

**22. Explain** When you are describing the rate that a race car goes around a track, should you use the term *speed* or *velocity* to describe the motion?

# **Applying Math**

- **23. Calculate Speed** A cyclist must travel 800 km. How many days will the trip take if the cyclist travels 8 h/day at an average speed of 16 km/h?
- **24. Calculate Acceleration** A satellite's speed is 10,000 m/s. After 1 min, it is 5,000 m/s. What is the satellite's acceleration?
- **25. Calculate Displacement** A cyclist leaves home and rides due east for a distance of 45 km. She returns home on the same bike path. If the entire trip takes 4 h, what is her average speed? What is her displacement?
- **26. Calculate Velocity** The return trip of the cyclist in question 13 took 30 min longer than her trip east, although her total time was still 4 h. What was her velocity in each direction?

Use the graph below to answer question 27.



**27. Interpret a Graph** Use the graph to determine which runner had the greatest speed.

# chapter 3 Standardized Test Practice

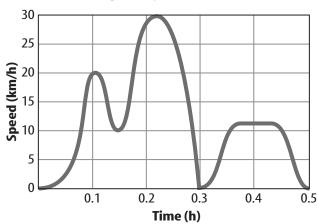
Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

# Multiple Choice

- **1.** Sound travels at a speed of 330 m/s. How long does it take for the sound of thunder to travel 1,485 m?
  - **A.** 45 s
  - **B.** 4.5 s
  - **c.** 4,900 s
  - **D.** 0.22 s

Use the graph below to answer questions 2-4.

# **Change in Speed over Time**



- **2.** The graph shows how a cyclist's speed changed over 0.5 h. What is the cyclist's average speed if the trip was 6 km?
  - **A.** 3 km/h
  - **B.** 10 km/h
  - **c.** 12 km/h
  - **D.** 20 km/h

# Test-Taking Tip

**Read Carefully** Read each question carefully for full understanding.

- **3.** Once the trip was started, how many times did the cyclist stop?
  - **A.** 0
  - **B.** 4
  - **c.** 2
  - **D.** 5
- **4.** What was the fastest speed the cyclist traveled?
  - **A.** 20 km/h
  - **B.** 30 km/h
  - **c.** 12 km/h
  - **D.** 10 km/h

Use the table below to answer questions 5 and 6.

Runner	Distance covered (km)	Time (min)	
Daisy	12.5	42	
Jane	7.8	38	
Bill	10.5	32	
Joe	8.9	30	

- **5.** What is Daisy's average speed?
  - **A.** 0.30 km/min
  - **B.** 530 km/min
  - **c.** 3.0 km/min
  - **D.** 3.4 km/min
- **6.** Which runner has the fastest average speed?
  - A. Daisy
  - **B.** Jane
  - **c.** Bill
  - **D.** Joe

- 7. A skier is going down a hill at a speed of 9 m/s. The hill gets steeper and her speed increases to 18 m/s in 3 s. What is her acceleration?
  - **A.**  $9 \text{ m/s}^2$
  - **B.**  $3 \text{ m/s}^2$
  - **c.**  $27 \text{ m/s}^2$
  - **D.**  $6 \text{ m/s}^2$
- **8.** Which of the following best describes an object with constant velocity?
  - **A.** It is changing direction.
  - **B.** Its acceleration is increasing.
  - **C.** Its acceleration is zero.
  - **D.** Its acceleration is negative.

# Gridded Response

**9.** If a car is traveling at a speed of 40 km/h and then comes to a stop in 5 s, what is its acceleration in m/s<sup>2</sup>?

# Short Response

# Use the table below to answer question 10.

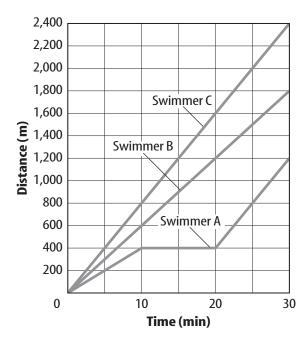
Car	Mass (kg)	Stopping Distance(m)
Α	1,000	80
В	1,250	100
С	1,500	120
D	2,000	160

- **10.** What is the relationship between a car's mass and its stopping distance?
- **11.** If the speedometer on a car indicates a constant speed, can you be sure the car is not accelerating? Explain.

# Extended Response

# Use the graph below to answer question 12.

# **Graphing Motion**



- **12.** The graph shows the motion of three swimmers during a 30-min workout. Describe the motion of the three swimmers.
- **13.** Where would you place the location of a reference point in order to describe the motion of a space probe traveling from Earth to Jupiter? Explain your choice.

# chapter



# BIG (Idea

Newton's laws of motion connect the change in an object's motion with the forces acting on it.

# 4.1 The First Two Laws of Motion

MAIN (Idea Unbalanced forces cause an object to accelerate.

# 4.2 Gravity

MAIN (Idea Gravity is an attractive force that any two objects with mass exert on each other.

# 4.3 The Third Law of Motion

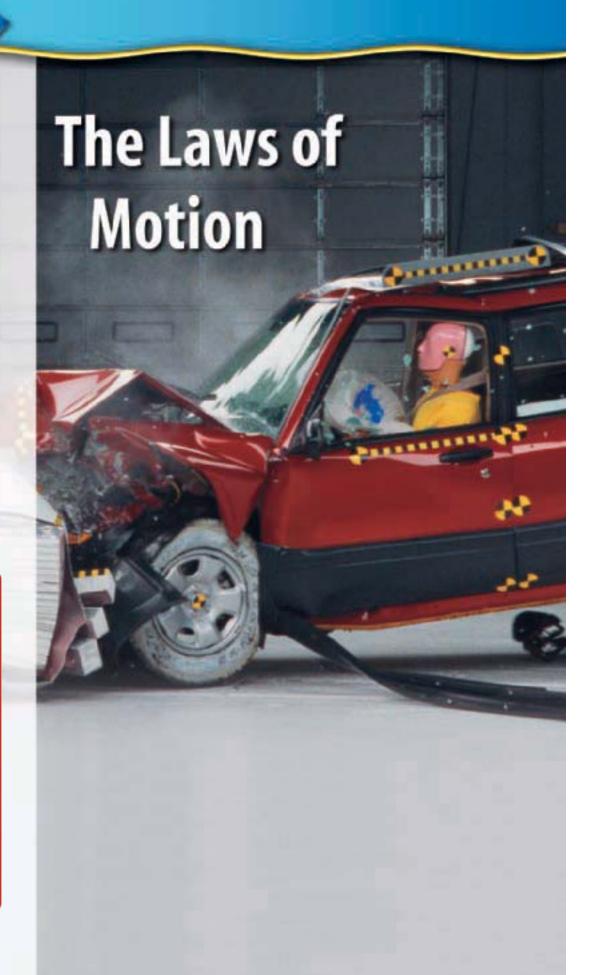
**MAIN** (Idea Forces between two objects are always exerted in pairs.

# Who's a dummy?

Crunch! This test dummy would have some explaining to do if this were a traffic accident. But in a test crash, the dummy plays an important role. The forces acting on it during a crash are measured and analyzed in order to learn how to make cars safer.

#### Science Journal

Predict which would be safer in a head-on crash—a car with a front that crumples or one with a front that doesn't crumple.



# **Start-Up Activities**



# **The Force of Gravity**

The force of Earth's gravity pulls all objects downward. However, objects such as rocks seem to fall faster than feathers or leaves. Do objects with more mass fall faster?

- 1. Complete the safety form.
- 2. Measure the mass of a softball, a tennis ball, and a flat sheet of paper. Copy the data table below and record the masses.
- 3. Drop the softball from a height of 2.5 m and use a stopwatch to measure the time it takes for the softball to hit the floor.

  Record the time in your data table.
- **4.** Repeat step 3 using the tennis ball and the flat sheet of paper. Record the times in your data table.
- Crumple the flat sheet of paper into a ball, and measure and record the time for it to fall 2.5 m.
- **6. Think Critically** Write a paragraph comparing the times it took each item to fall 2.5 m. From your data, infer if the speed of a falling object depends on the object's mass.

**Falling Object Data** 

Object	Mass	Time
Softball		
Tennis ball		
Flat paper		
Crumpled paper		

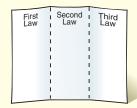


The Laws of Motion Make the following Foldable to help you better understand Newton's laws of motion as you read the chapter.

Fold the top of a vertical piece of paper down and the bottom up to divide the paper into thirds.



STEP 2 Unfold and label the rows First Law, Second Law, Third Law.



**Find Main Ideas** As you read the chapter, list the main ideas in the sections on the laws of motion under the appropriate column.



Preview this chapter's content and activities at gpescience.com

# 1

# The First Two Laws of Motion

# **Reading Guide**

# What You'll Learn

- Define Newton's first law of motion.
- Explain how inertia and mass are related.
- Define Newton's second law of motion.
- Apply Newton's second law of motion.

# Why It's Important

Newton's first two laws of motion explain how forces cause the motion of objects to change.

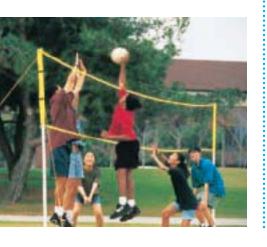
# Review Vocabulary

**net force:** the combination of all forces acting on an object

# **New Vocabulary**

- first law of motion
- inertia
- second law of motion

**Figure 1** Newton's laws of motion apply to all objects, including the volleyball and the volleyball players.



# **Newton's Laws of Motion**

When you lift a backpack, you exert a force on an object and cause it to move. The backpack initially was at rest. The force you exerted caused its velocity to change. But if you push downward on a table, the table doesn't move. The force you applied did not cause the velocity of the table to change. How are forces and motion related?

The British scientist Isaac Newton, who lived from 1642 to 1727, published a set of three rules in 1687 that explained how forces and motion are related. These three rules are called Newton's laws of motion. They apply to the motion of all objects you encounter every day, such as those in **Figure 1**, as well as to the motion of planets, stars, and galaxies.

# **The First Law of Motion**

Newton's first law of motion describes how an object moves when the net force acting on it is zero. According to Newton's **first law of motion**, if the net force acting on an object is zero, the object remains at rest, or if the object is moving, it continues moving in a straight line with constant speed. The first law of motion means that if the forces acting on an object are balanced, then the velocity of the object doesn't change.

Only Unbalanced Forces Change Velocity The first law of motion connects forces with changes in motion. For example, suppose a skateboard is at rest. The skateboard doesn't move until you give it a push. Then the velocity of the skateboard increases while you are pushing it. The forces on the skateboard are unbalanced while you are pushing on it. As a result, the velocity of the skateboard changes as its speed increases.

However, after the skateboard leaves your hand, it slows down and stops. It might seem that the skateboard stops moving because there are no forces acting on it. However, there is an unbalanced frictional force that acts on the skateboard as it rolls. This is the force that causes the skateboard to stop. The unbalanced frictional force causes the velocity of the skateboard to change as its speed decreases. The velocity of an object changes only when there are unbalanced forces acting on it.

# **Inertia and Mass**

All objects have a property called inertia. **Inertia** is the tendency of an object to resist a change in its motion. The dirt bike in **Figure 2** has inertia that tends to keep it moving with a constant velocity when its rider tries to steer around a curve. The inertia of an object depends on the object's mass. The greater the mass of an object, the greater its inertia.

For example, a bowling ball has more mass than a volleyball. Which would be harder to stop—a volleyball or a bowling ball rolling at the same speed? You would have to exert a greater force on the bowling ball to make it stop. The bowling ball has more inertia than the volleyball because it has more mass.

Reading Check

How does the inertia of an object depend on the object's mass?





# **Observing Inertia**

# 

- 1. Complete the safety form.
- Create an inclined plane using a board and textbooks.
- 3. Place a small object in a cart and let the cart roll down the plane. Record the results.
- Secure the object in the cart with rubber bands. Let the cart roll down the plane and record your results.

#### **Analysis**

- 1. Identify the forces acting on the object in the cart in both runs.
- **2.** Explain how safety belts reduce the risk of injury in a car crash.

**Figure 2** Inertia causes the bike to move in a straight line despite the efforts of the rider to steer the bike around the curve.





**Figure 3** The inertia of the boxes causes them to keep moving after the cart has been brought to a sudden stop.

**Describe** the velocity of the boxes just after the cart stops.

**Inertia and the First Law of Motion** According to the first law of motion, the velocity of an object doesn't change unless the forces acting on the object are unbalanced. In other words, if you observe a change in an object's velocity, you know an unbalanced force acted on it. This is similar to the definition of inertia—an object resists a change in its motion. As a result, the first law of motion sometimes is called the law of inertia.

Inertia and the first law of motion explain why the boxes in **Figure 3** slide off the cart when the cart comes to a sudden stop. The student applies an unbalanced force to the cart that makes it stop. However, the inertia of the boxes causes them to keep moving even after the cart stops.

# **Figure 4** This crash test dummy is not restrained in this low-speed crash. Inertia causes the dummy to slam into the steering wheel.

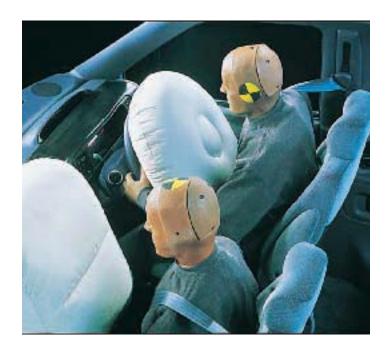
# What happens in a crash?

The first law of motion can explain what happens in a car crash. When a car traveling 50 km/h collides head-on with



something solid, the car crumples, slows down, and stops within about 0.1 s. Any passenger not wearing a safety belt continues to move forward at the same speed the car was traveling. Within about 0.02 s after the car stops, unbelted passengers slam into the dashboard, windshield, or steering wheel, as shown in **Figure 4.** Passengers in the back seat might slam into the backs of the front seats. Because of their inertia, they are traveling at the car's original speed of 50 km/h—about the same speed they would reach falling from a three-story building.

**Safety Belts** In **Figure 5** the crash test dummies are restrained with safety belts. As a result, they slow down at the same rate that the car slows down. However, the force exerted on a person that slows from 50 km/h to 0 km/h in 0.1 s is about 14 times as large as the force of gravity on the person. To further reduce the force acting on a person, the seat belt loosens slightly, increasing the time it takes to slow the person. Increasing the time needed to stop reduces the force exerted on the person. The safety belt also prevents the person from being thrown out of the car. Car-safety experts say that about half the people who die in car crashes would survive if they wore safety belts.





What are two advantages of wearing a safety belt in a crash?

# **The Second Law of Motion**

According to Newton's first law of motion, unbalanced forces cause the velocity of an object to change. Newton's second law of motion describes how the net force on an object, its mass, and its acceleration are related.

Force and Acceleration What's different about throwing a ball horizontally as hard as you can and tossing it gently? When you throw hard, the net force on the ball is greater than when you toss it. Also, the ball has a greater velocity when it leaves your hand. As a result, the hard-thrown ball has a greater change in velocity, and this change can occur over a shorter period of time. Recall that acceleration is the change in velocity divided by the time needed for the change to occur. So, a hard-thrown ball has a greater acceleration than a gently-thrown ball.

**Mass and Acceleration** If you throw a baseball and a softball with the same amount of force, why does the baseball move faster? A softball has more mass than a baseball. Even though the net force exerted on both balls is the same, the softball has less velocity when it leaves your hand than the baseball does. If it takes the same amount of time to throw both balls, the acceleration of the softball is less than that of the baseball. So, the acceleration of an object depends on its mass, as well as the net force exerted on it. Net force, mass, and acceleration are related.

**Figure 5** These crash test dummies were restrained with safety belts in this crash. This prevented the dummies from hitting the dashboard or windshield.



**Topic: Motion in Sports**Visit **gpescience.com** for Web links to information about methods used to analyze the motions of athletes.

**Activity** Choose a sport and write a report on how analyzing the motions involved in the sport can improve performance and reduce injuries.

# **The Second Law of Motion**

Newton's **second law of motion** states that the acceleration of an object is in the same direction as the net force on the object, and that the acceleration can be calculated from the following equation:

#### **Newton's Second Law of Motion**

acceleration (in meters/second<sup>2</sup>) = 
$$\frac{\text{net force (in newtons)}}{\text{mass (in kilograms)}}$$
$$a = \frac{F_{\text{net}}}{m}$$

# **Applying Math**

# **Solve a Simple Equation**

**THE ACCELERATION OF A SLED** You push a friend on a sled. Your friend and the sled together have a mass of 70 kg. If the net force on the sled is 35 N, what is the sled's acceleration?

**IDENTIFY** known values and the unknown value

Identify the known values:

The net force on the sled is 35 N  $F_{net} = 35 \text{ N}$ 

Your friend and the sled together have a mass of 70 kg m = 70 kg

Identify the unknown value:

What is the sled's acceleration?  $\boxed{\text{means}}$   $a = ? \text{ m/s}^2$ 

# **SOLVE** the problem

Substitute the known values  $F_{\text{net}} = 35 \text{ N}$  and m = 70 kg into the equation for Newton's second law of motion:

$$a = \frac{F_{\text{net}}}{m} = \frac{35 \text{ N}}{70 \text{ kg}} = 0.5 \frac{\text{N}}{\text{kg}} = 0.5 \frac{\text{kg m}}{\text{s}^2} \times \frac{1}{\text{kg}} = 0.5 \text{ m/s}^2$$

# **CHECK** your answer

Does your answer seem reasonable? Check your answer by multiplying the acceleration you calculated by the mass given in the problem. The result should be the net force given in the problem.

# **Practice Problems**

- **1.** If the mass of a helicopter is 4,500 kg, and the net force on it is 18,000 N, what is the helicopter's acceleration?
- 2. What is the net force on a dragster with a mass of 900 kg if its acceleration is 32.0 m/s<sup>2</sup>?
- **3.** A car is being pulled by a tow truck. What is the car's mass if the net force on the car is 3,000 N and it has an acceleration of 2.0 m/s<sup>2</sup>?

For more practice problems go to page 879, and visit Math Practice at gpescience.com.

Calculating Net Force with the Second Law Newton's second law also can be used to calculate the net force if mass and acceleration are known. To do this, the equation for Newton's second law must be solved for the net force, *F.* To solve for the net force, multiply both sides of the above equation by the mass:

$$m \times \frac{F_{\text{net}}}{m} = ma$$

The mass, *m*, on the left side cancels, giving the equation:

$$F_{\text{net}} = ma$$

For example, when the tennis player in **Figure 6** hits a ball, the ball might be in contact with the racket for only a few thousandths of a second. Because the ball's velocity changes over such a short period of time, the ball's acceleration could be as high as 5,000 m/s<sup>2</sup>. The ball's mass is 0.06 kg, so the net force exerted on the ball would be:

$$F_{\rm net} = ma = (0.06 \text{ kg}) (5,000 \text{ m/s}^2) = 300 \text{ kg m/s}^2 = 300 \text{ N}$$



**Figure 6** The tennis racket exerts a force on the ball that causes it to accelerate.

# section

# review

# **Summary**

# **Inertia and the First Law of Motion**

- According to Newton's first law of motion, the velocity of an object does not change unless an unbalanced net force acts on the object.
- The inertia of an object is the tendency of the object to resist a change in motion.
- The larger the mass of an object, the greater its inertia.
- In a car crash, inertia causes an unrestrained passenger to continue moving at the speed of the car before the crash.

#### The Second Law of Motion

- The acceleration of an object depends on the mass of the object and the net force exerted on the object.
- According to Newton's second law of motion, the acceleration of an object is in the direction of the net force on the object, and can be calculated from this equation:

$$a = \frac{F_{\text{net}}}{m}$$

# **Self Check**

- 1. **Infer** whether the inertia of an object changes as the object's velocity changes.
- 2. Determine whether or not there must be an unbalanced force acting on any object that is moving. Explain.
- **3. Determine** whether or not there can be forces acting on an object that is at rest. Explain.
- **4. Infer** the net force on a refrigerator if you push on the refrigerator and it doesn't move.
- **5. Think Critically** Describe three situations in which a force changes the velocity of an object. Let at least one of the situations involve the force due to gravity.

# **Applying Math**

- **6. Calculate Mass** You push yourself on a skateboard with a force of 30 N and accelerate at 0.5 m/s<sup>2</sup>. Find the mass of you and the skateboard together.
- 7. Calculate Net Force You push a book that has a mass of 2.0 kg so that it has an acceleration of 1.0  $m/s^2$ . What is the net force on the book?

# **Reading Guide**

# What You'll Learn

- **Describe** the gravitational force.
- Distinguish between mass and weight.
- Explain why objects that are thrown will follow a curved path.
- Compare circular motion with motion in a straight line.

# Why It's Important

There is a gravitational force between you and every other object in the universe.

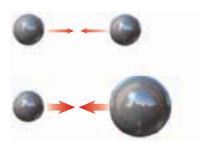
# Review Vocabulary

**acceleration:** the rate of change of velocity which occurs when an object changes speed or direction

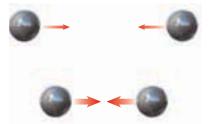
# **New Vocabulary**

- gravity
- weight
- centripetal acceleration
- centripetal force

**Figure 7** The gravitational force between two objects depends on their masses and the distance between them.



Increasing the mass of either object increases the gravitational force between them.



If the objects are closer together, the gravitational force between them increases.

# What is gravity?

There's a lot about you that's attractive. At this moment, you are exerting an attractive force on everything around you—your desk, your classmates, even the planet Jupiter millions of kilometers away. It's the attractive force of gravity.

Anything that has mass is attracted by the force of gravity. **Gravity** is an attractive force between any two objects that depends on the masses of the objects and the distance between them. This force increases as the mass of either object increases, or as the objects move closer, as shown in **Figure 7.** 

You can't feel any gravitational attraction between you and this book because the force is weak. Only Earth is both close enough and has a large enough mass that you can feel its gravitational attraction. While the Sun has much more mass than Earth, the Sun is too far away to exert a noticeable gravitational attraction on you. And while this book is close, it doesn't have enough mass to exert an attraction you can feel.

**Gravity—A Basic Force** Gravity is one of the four basic forces. The other basic forces are the electromagnetic force, the strong nuclear force, and the weak nuclear force. The two nuclear forces only act on particles in the nuclei of atoms. Electricity and magnetism are caused by the electromagnetic force. Chemical interactions between atoms and molecules also are due to the electromagnetic force.

# The Law of Universal Gravitation

For thousands of years, people have observed the night sky and collected data on the motions of the stars and planets. Isaac Newton used some of these data on the motions of planets to formulate the law of universal gravitation, which he published in 1687. This law can be written as the following equation.

#### The Law of Universal Gravitation

gravitational force = (constant) 
$$\times \frac{(\text{mass 1}) \times (\text{mass 2})}{(\text{distance})^2}$$
  
 $F = G \frac{m_1 m_2}{d^2}$ 

In this equation G is a constant called the universal gravitational constant, and d is the distance between the two masses,  $m_1$  and  $m_2$ . The law of universal gravitation enables the force of gravity to be calculated between any two objects if their masses and the distance between them are known.

**The Range of Gravity** According to the law of universal gravitation, the gravitational force between two masses decreases rapidly as the distance between the masses increases. For example, if the distance between two objects increases from 1 m to 2 m, the gravitational force between them becomes one fourth as large. If the distance increases from 1 m to 10 m, the gravitational force between the objects is one hundredth as large. However, no matter how far apart two objects are, the gravitational force between them never completely disappears. As a result, gravity is called a long-range force.

Reading Check Why is gravity called a long-range force?

Finding Other Planets Earth's motion around the Sun is affected by the gravitational pulls of the other planets in the solar system. In the same

way, the motion of every planet in the solar system is affected by the gravitational pulls of all the other planets.

In the 1840s the most distant planet known was Uranus. The motion of Uranus calculated from the law of universal gravitation disagreed slightly with its observed motion. Some astronomers suggested that there must be an undiscovered planet affecting the motion of Uranus. Using the law of universal gravitation and Newton's laws of motion, two astronomers independently calculated the orbit of this planet. As a result of these calculations, the planet Neptune, shown in **Figure 8**, was found in 1846.



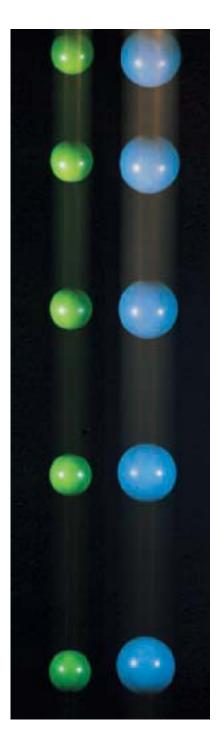
## **Topic: Gravity on Other Planets**

Visit gpescience.com for Web links to information about the gravitational acceleration near the surface of different planets in the solar system.

**Activity** Make a graph with the gravitational acceleration on the y-axis, and the planet's mass on the x-axis. Infer from your graph how the gravitational acceleration depends on a planet's mass.



**Figure 8** The location of the planet Neptune in the night sky was correctly predicted using Newton's laws of motion and the law of universal gravitation.



**Figure 9** Time-lapse photography shows that two balls of different masses fall at the same rate.

# **Earth's Gravitational Acceleration**

If you dropped a bowling ball and a marble at the same time, which would hit the ground first? Suppose the effects of air resistance are small enough to be ignored. When all forces except gravity acting on an a falling object can be ignored, the object is said to be in free fall. Then all objects near Earth's surface would fall with the same acceleration, just like the two balls in **Figure 9.** 

Close to Earth's surface, the acceleration of an object in free fall is  $9.8 \text{ m/s}^2$ . This acceleration is the gravitational acceleration and is given the symbol g. By the second law of motion, the gravitational force exerted by Earth on a falling object is the object's mass times the gravitational acceleration. The gravitational force can be calculated from this equation:

```
Gravitational Force Equation

gravitational force (N)

= mass (kg) \times gravitational acceleration (m/s<sup>2</sup>)

F = mg
```

For example, the gravitational force on a skydiver with a mass of 60 kg would be

$$F = mg = (60 \text{ kg}) (9.8 \text{ m/s}^2) = 588 \text{ N}$$

**Weight** Even if you are not falling, the force due to Earth's gravity still is pulling you downward. If you are standing on a floor, the net force on you is zero. The force due to Earth's gravity pulls you downward, but the floor exerts an upward force on you that balances gravity's downward pull.

Whether you are standing, jumping, or falling, Earth exerts a gravitational force on you. The gravitational force exerted on an object is called the object's **weight**. The weight of an object on Earth is equal to the gravitational force exerted by Earth on the object. As a result, near Earth's surface an object's weight can be calculated from this equation:

# Weight Equation weight (N) = mass (kg) $\times$ gravitational acceleration (m/s<sup>2</sup>) W = mg

On Earth, where g equals 9.8 m/s<sup>2</sup>, a cassette tape weighs about 0.5 N, a backpack full of books could weigh 100 N, and a jumbo jet weighs about 3.4 million N.

**Weight and Mass** Weight and mass are not the same. Weight is a force and mass is a measure of the amount of matter an object contains. However, according to the weight equation on the previous page, weight and mass are related. Weight increases as mass increases.

The weight of an object usually is the gravitational force between the object and Earth. But the weight of an object can change, depending on the gravitational force on the object. For example, the acceleration due to gravity on the Moon is 1.6 m/s<sup>2</sup>, about one sixth as large as Earth's gravitational acceleration. As a result, a person, like the astronaut in Figure 10, would weigh only about one sixth as much on the Moon as on Earth. Table 1 shows how various weights on Earth would be different on the Moon and some of the planets.



Reading Check How are weight and mass related?

# **Weightlessness and Free Fall**

You've probably seen pictures of astronauts and equipment floating inside the space shuttle. Any item that is not fastened down seems to float throughout the cabin. They are said to be experiencing the sensation of weightlessness.

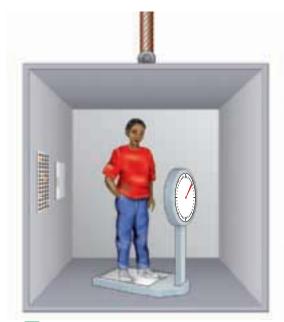
However, for a typical mission, the shuttle orbits Earth at an altitude of about 400 km. According the law of universal gravitation, at 400-km altitude the force of Earth's gravity is about 90 percent as strong as it is at Earth's surface. So an astronaut with a mass of 80 kg still would weigh about 700 N in orbit, compared with a weight of about 780 N at Earth's surface.

Table 1 Weight Comparison Table					
Weight on	Weight on Other Bodies in the Solar System (N)				
Earth (N)	Moon	Venus	Mars	Jupiter	Saturn
75	12	68	28	190	87
100	17	90	38	254	116
150	25	135	57	381	174
500	84	450	190	1,270	580
700	119	630	266	1,778	812
2,000	333	1,800	760	5,080	2,320

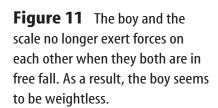


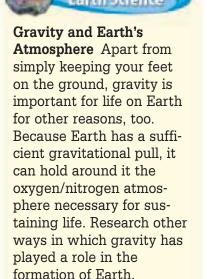
**Figure 10** On the Moon, the gravitational force on the astronaut is less than it is on Earth. As a result, the astronaut can take longer steps and jump higher than on Earth.

**Describe** how the astronaut's mass and weight on the Moon compare to his mass and weight on Earth.



A When the elevator is stationary, the scale shows the boy's weight.







B If the elevator were in free fall, the scale would show a zero weight.

Floating in Space Why do objects seem weightless in orbit? Think about measuring your weight. When you stand on a scale, as in Figure 11A, the net force on you is zero. The scale exerts an upward force on you equal to your weight. Now suppose you stand on a scale in an elevator that is in free fall, as shown in Figure 11B. Then the only force acting on you is the gravitational force. You and the scale no longer exert forces on each other. The scale would show zero weight, even though the gravitational force on you hasn't changed.

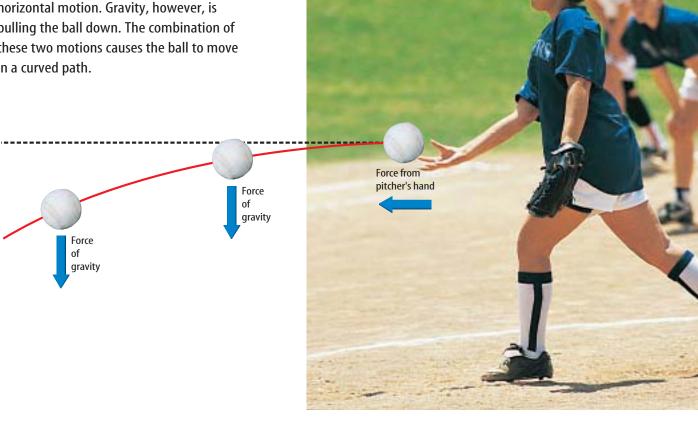
# **Meading Checks** What is the only force on an object in free fall?

A space shuttle in orbit is in free fall, but it is falling around Earth, rather than straight downward. Everything in the orbiting space shuttle is falling around Earth at the same rate, in the same way you and the scale were falling in the elevator. Objects in the shuttle seem to be floating because they are all falling with the same acceleration.

# **Projectile Motion**

If you've tossed a ball to someone, you've probably noticed that thrown objects don't always travel in straight lines. They curve downward. Anything that's thrown or shot through the air is called a projectile. Earth's gravity causes projectiles to follow a curved path.

**Figure 12** The pitcher gives the ball a horizontal motion. Gravity, however, is pulling the ball down. The combination of these two motions causes the ball to move in a curved path.



Horizontal and Vertical Motions When you throw a ball, like the pitcher in **Figure 12**, the force exerted by your hand pushes the ball forward. This force gives the ball horizontal motion. After you let go of the ball, no force accelerates it forward, so its horizontal velocity is constant, if you ignore air resistance.

However, when you let go of the ball, gravity can accelerate it downward, giving it vertical motion. Now the ball has constant horizontal velocity but increasing vertical velocity. Gravity exerts an unbalanced force on the ball, changing the direction of its path from only forward to forward and downward. The result of these two motions is that the ball appears to travel in a curve, even though its horizontal and vertical motions are completely independent of each other.

**Horizontal and Vertical Distance** If you were to throw a ball as hard as you could from shoulder height in a perfectly horizontal direction, would it take longer to reach the ground than if you dropped a ball from the same height? Surprisingly, it won't. A thrown ball and one dropped will hit the ground at the same time. Both balls in Figure 13 travel the same vertical distance in the same amount of time. However, the ball thrown horizontally travels a greater horizontal distance than the ball that is dropped.



Figure 13 Multiflash photography shows that each ball has the same acceleration downward, whether it's thrown or dropped.



**Figure 14** When the ball moves through the curved portions of the tube, it is accelerating because its velocity is changing. **Identify** the forces acting on the ball as it falls through the tube.



# Observing Centripetal Force

# **Procedure**

- 1. Complete the safety form.
- 2. Thread a string about 1 m long through the holes of a plastic, slotted ball.
- **3.** Swing the ball in a vertical circle.
- 4. Swing the ball at different speeds and observe the motion of the ball and the tension in the string.

#### **Analysis**

- 1. What force does the string exert on the ball when the ball is at the top, sides, and bottom of the swing?
- 2. How does the tension in the string depend on the speed of the ball?

# **Centripetal Force**

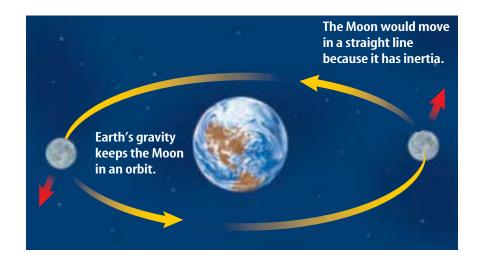
Look at the path the ball follows as it travels through the curved tube in **Figure 14.** The ball may accelerate in the straight sections of the pipe maze if it speeds up or slows down. However, when the ball enters a curve, even if its speed does not change, it is accelerating because its direction is changing. When the ball goes around a curve, the change in the direction of the velocity is toward the center of the curve. Acceleration toward the center of a curved or circular path is called **centripetal acceleration.** 

According to the second law of motion, when the ball has centripetal acceleration, the direction of the net force on the ball also must be toward the center of the curved path. The net force exerted toward the center of a curved path is called a **centripetal force**. For the ball moving through the tube, the centripetal force is the force exerted by the walls of the tube on the ball.

**Centripetal Force and Traction** When a car rounds a curve on a highway, a centripetal force must be acting on the car to keep it moving in a curved path. This centripetal force is the frictional force, or the traction, between the tires and the road surface. If the road is slippery and the frictional force is small, the centripetal force might not be large enough to keep the car moving around the curve. Then the car will slide in a straight line. Anything that moves in a circle, such as the people on the amusement park ride in **Figure 15**, is doing so because a centripetal force is accelerating it toward the center.



**Figure 15** Centripetal force keeps these riders moving in a circle.



**Figure 16** The Moon would move in a straight line except that Earth's gravity keeps pulling it toward Earth. This gives the Moon a nearly circular orbit.

**Gravity Can Be a Centripetal Force** Imagine whirling an object tied to a string above your head. The string exerts a centripetal force on the object that keeps it moving in a circular path. In the same way, Earth's gravity exerts a centripetal force on the Moon that keeps it moving in a nearly circular orbit, as shown in **Figure 16.** 

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# **Summary**

#### **Gravity**

- According to the law of universal gravitation, the gravitational force between two objects depends on the masses of the objects and the distance between them.
- The acceleration due to gravity near Earth's surface has the value 9.8 m/s<sup>2</sup>.
- Near Earth's surface, the gravitational force on an object with mass, m, is given by:

$$F = mq$$

#### Weight

 The weight of an object is related to its mass according to the equation:

$$W = mq$$

• An object in orbit seems to be weightless because it is falling around Earth.

#### **Projectile Motion and Centripetal Force**

- Projectiles follow a curved path because their horizontal motion is constant, but gravity causes the vertical motion to be changing.
- The net force on an object moving in a circular path is called the centripetal force.

# **Self Check**

- Describe how the gravitational force between two objects depends on the mass of the objects and the distance between them.
- Distinguish between the mass of an object and the object's weight.
- **3. Explain** what causes the path of a projectile to be curved
- **4. Describe** the force that causes the planets to stay in orbit around the Sun.
- **5. Think Critically** Suppose Earth's mass increased, but its diameter didn't change. How would the acceleration due to gravity near Earth's surface change?

# **Applying Math**

- **6. Calculate Weight** On Earth, what is the weight of a large-screen TV that has a mass of 75 kg?
- **7. Calculate Gravity on Mars** Find the acceleration due to gravity on Mars if a person with a mass of 60.0 kg weighs 222 N on Mars.
- **8. Calculate Force** Find the force exerted by a rope on a 10-kg mass that is hanging from the rope.



# GRAVITY AND AIR RESISTANCE

If you dropped a bowling ball and a feather from the same height on the Moon, they would both hit the surface at the same time. All objects dropped on Earth are attracted to Earth with the same acceleration. But on Earth, a bowling ball and a feather will not hit the ground at the same time. Air resistance slows the feather down.

# Real-World Problem

How does air resistance affect the acceleration of falling objects?

#### Goals

- Measure the effect of air resistance on sheets of paper with different shapes.
- **Design** and create a shape from a piece of paper that maximizes air resistance.

#### **Materials**

paper (4 sheets of equal size) stopwatch scissors masking tape meterstick

# Safety Precautions 🗫 📨 🔚

# Procedure

- 1. Complete the safety form.
- **2.** Copy the data table above in your Science Journal, or create it on a computer.
- Measure a height of 2.5m on the wall and mark the height with a piece of masking tape.
- 4. Have one group member drop the flat sheet of paper from the 2.5-m mark. Use the stopwatch to time how long it takes for the paper to reach the ground. Record your time in your data table.

Effects of Air Resistance			
Paper Type	Time		
Flat paper	Do not write		
Loosely crumpled paper	in this book.		
Tightly crumpled paper			
Your paper design			

- **5.** Crumple a sheet of paper into a loose ball and repeat step 4.
- **6.** Crumple a sheet of paper into a tight ball and repeat step 4.
- 7. Use scissors to shape a piece of paper so that it will fall slowly. You may cut, tear, or fold your paper into any design you choose.

# Conclude and Apply-

- Compare the falling times of the different sheets of paper.
- Explain why the different-shaped papers fell at different speeds.
- 3. Explain how your design caused the force of air resistance on the paper to be greater than the air resistance on the other paper shapes.

# Communicating Your Data

Compare your paper design with the designs created by your classmates. As a class, compile a list of characteristics that increase air resistance.

# **The Third Law of Motion**

# **Reading Guide**

# What You'll Learn

- State Newton's third law of motion.
- Identify action and reaction forces.
- Calculate momentum.
- Recognize when momentum is conserved.

# Why It's Important

The third law of motion explains how you affect Earth when you walk, and how Earth affects you.

# **Review Vocabulary**

**velocity:** describes the speed and direction of a moving object

# **New Vocabulary**

- third law of motion
- momentum
- law of conservation of momentum

# **Newton's Third Law**

Push against a wall and what happens? If the wall is sturdy enough, usually nothing happens. If you pushed against a wall while wearing roller skates, you would go rolling backward. Your action on the wall produced a reaction—movement backward. This is a demonstration of Newton's third law of motion.

The **third law of motion** describes action-reaction pairs this way: When one object exerts a force on a second object, the second one exerts a force on the first that is equal in strength and opposite in direction. Another way to say this is "to every action force there is an equal and opposite reaction force."

**Action and Reaction** When a force is applied in nature, a reaction force occurs at the same time. When you jump on a

trampoline, for example, you exert a downward force on the trampoline. Simultaneously, the trampoline exerts an equal force upward, sending you high into the air.

Action and reaction forces are acting on the two skaters in **Figure 17.** The male skater is pulling upward on the female skater, while the female skater is pulling downward on the male skater. The two forces are equal, but in opposite directions.

**Figure 17** According to Newton's third law of motion, the two skaters exert forces on each other. The two forces are equal, but in opposite directions.





**Space Medicine** Astronauts who stay in outer space for extended periods of time may develop health problems. Their muscles, for example, may begin to weaken because they don't have to exert as much force to get the same reaction as they do on Earth. A branch of medicine called space medicine deals with the possible health problems that astronauts may experience. Research some other health risks that are involved in going into outer space.

**Figure 18** Newton's third law enables the rocket engine to push the car forward. The rocket engine pushes the hot gases produced by burning fuel backward out of the engine's nozzle. By the third law, the gases exert a force of equal size on the engine in the forward direction.

**Infer** the direction of the car's acceleration when the rocket engine is fired.

Action and Reaction Forces Don't Cancel If action and reaction forces are equal, you might wonder how some things ever happen. For example, how does a swimmer move through the water in a pool if each time she pushes on the water, the water pushes back on her? According to the third law of motion, action and reaction forces act on different objects. Thus, even though the forces are equal, they are not balanced because they act on different objects. In the case of the swimmer, as she "acts" on the water, the "reaction" of the water pushes her forward. Thus, a net force, or unbalanced force, acts on her so a change in her motion occurs. As the swimmer moves forward in the water, how does she make the water move?

Reading Check Why don't action and reaction forces cancel?

**Rocket Propulsion** Suppose you are standing on skates holding a softball. You exert a force on the softball when you throw the softball. According to Newton's third law, the softball exerts a force on you. This force pushes you in the direction opposite the softball's motion. Rockets use the same principle to move even in the vacuum of outer space. In the rocket engine, burning fuel produces hot gases. The rocket engine exerts a force on these gases and causes them to escape out the back of the rocket. By Newton's third law, the gases exert a force on the rocket and push it forward. The car in Figure 18 uses a rocket engine to propel it forward. Figure 19 shows how rockets were used to travel to the Moon.



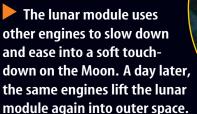
# NATIONAL GEOGRAPHIC VISUALIZING ROCKET MOTION

# Figure 19

n the afternoon of July 16, 1969, Apollo 11 lifted off from Cape Kennedy, Florida, bound for the Moon. Eight days later, the spacecraft returned to Earth, splashing down safely in the Pacific Ocean. The motion of the spacecraft to the Moon and back is governed by Newton's laws of motion.



Apollo 11 roars toward the Moon.
At launch, a rocket's engines must produce enough force and acceleration to overcome the pull of Earth's gravity.
A rocket's liftoff is an illustration of Newton's third law: For every action there is an equal and opposite reaction.





As Apollo rises, it burns fuel and ejects its rocket booster engines. This decreases its mass, and helps Apollo move faster. This is Newton's second law in action: As mass decreases, acceleration can increase.





▲ The lunar module returns to the *Apollo* spacecraft, which fires its engines to start it moving toward Earth. As the spacecraft gets closer to Earth, the gravitational force exerted by Earth becomes larger, continually increasing the acceleration of the spacecraft.

# **Momentum**

A moving object has a property called momentum that is related to how much force is needed to change its motion. The **momentum** of an object is the product of its mass and velocity. Momentum is given the symbol p and can be calculated with the following equation:

## **Momentum Equation**

momentum (kg m/s) = mass (kg) × velocity (m/s)  

$$p = mv$$

The unit for momentum is kg·m/s. Notice that momentum has a direction because velocity has a direction.

# **Applying Math**

# **Solve a Simple Equation**

**THE MOMENTUM OF A SPRINTER** At the end of a race, a sprinter with a mass of 80 kg has a speed of 10 m/s. What is the sprinter's momentum?

# **IDENTIFY** known values and the unknown value

#### Identify the known values:

a sprinter with a mass of 80 kg 
$$m = 80 \text{ kg}$$

has a speed of 10 m/s 
$$v = 10$$
 m/s

#### Identify the unknown value:

What is the sprinter's momentum? means  $p = ? \text{kg} \cdot \text{m/s}$ 

# **SOLVE** the problem

Substitute the known values m = 80 kg and v = 10 m/s into the momentum equation:

$$p = mv = (80 \text{ kg}) (10 \text{ m/s}) = 800 \text{ kg} \cdot \text{m/s}$$

## **CHECK** your answer

Does your answer seem reasonable? Check your answer by dividing the momentum you calculated by the mass given in the problem. The result should be the speed given in the problem.

#### **Practice Problems**

- 1. What is the momentum of a car with a mass of 1,300 kg traveling at a speed of 28 m/s?
- 2. A baseball thrown by a pitcher has a momentum of 6.0 kg·m/s. If the baseball's mass is 0.15 kg, what is the baseball's speed?
- 3. What is the mass of a person walking at a speed of 0.8 m/s if their momentum is 52.0 kg·m/s?

For more practice problems go to page 879, and visit Math Practice at gpescience.com.





**Law of Conservation of Momentum** The momentum of an object doesn't change unless its mass, velocity, or both change. Momentum, however, can be transferred from one object to another. Consider the game of pool shown in **Figure 20.** 

When the cue ball hits the group of balls that are motionless, the cue ball slows down and the rest of the balls begin to move. The momentum the group of balls gained is equal to the momentum that the cue ball lost. The total momentum of all the balls just before and after the collision would be the same. If no other forces act on the balls, their total momentum is conserved—it isn't lost or created. This is the law of conservation of momentum—if a group of objects exerts forces only on each other, their total momentum doesn't change.

**Figure 20** Momentum is transferred in collisions. A Before the collision, only the cue ball has momentum. B When the cue ball strikes the other balls, it transfers some of its momentum to them.

## section review

# **Summary**

#### **Newton's Third Law**

- According to Newton's third law of motion, for every action force, there is an equal and opposite reaction force.
- Action and reaction forces act on different objects.

#### **Momentum**

• The momentum of an object is the product of its mass and velocity:

p = mv

#### The Law of Conservation of Momentum

- According to the law of conservation of momentum, if objects exert forces only on each other, their total momentum is conserved.
- In a collision, momentum is transferred from one object to another.

## **Self Check**

- 1. **Determine** You push against a wall with a force of 50 N. If the wall doesn't move, what is the net force on you?
- **2. Explain** how a rocket can move through outer space where there is no matter for it to push on.
- 3. Compare the momentum of a 6,300-kg elephant walking 0.11 m/s and a 50-kg dolphin swimming 10.4 m/s.
- **4. Describe** what happens to the momentum of two billiard balls that collide.
- 5. Think Critically A ballet director assigns slow, graceful steps to larger dancers, and quick movements to smaller dancers. Why is this plan successful?

## **Applying Math**

6. Calculate Momentum What is the momentum of a 100-kg football player running at a speed of 4 m/s?



### Goals

- **Observe** and calculate the momentum of different balls.
- **Compare** the results of collisions involving different amounts of momentum.

## **Materials**

meterstick softball racquetball tennis ball baseball stopwatch masking tape balance

# **Safety Precautions**



# The Momentum of Colliding Objects

# Real-World Problem

Many scientists hypothesize that dinosaurs became extinct 65 million years ago when an asteroid collided with Earth. The asteroid's diameter was probably no more than 10 km. Earth's diameter is more than 12,700 km. How could an object that size change Earth's climate enough to cause the extinction of animals that had dominated life on Earth for 140 million years? The asteroid could have caused such

damage because it may have been traveling at a velocity of 50 m/s, and had a huge amount of momentum. The combination of an object's velocity and mass will determine how much force it can exert. How do the mass and velocity of a moving object affect its momentum?



Momentum of Colliding Balls					
Action	Time	Velocity	Mass	Momentum	Distance Softball Moved
Racquetball rolled slowly					
Racquetball rolled quickly					
Tennis ball rolled slowly		Do not	write in	this book.	
Tennis ball rolled quickly					
Baseball rolled slowly					
Baseball rolled quickly					

# Using Scientific Methods

# Procedure

- 1. Complete the safety form.
- **2.** Copy the data table on the previous page in your Science Journal.
- **3.** Use the balance to measure the mass of the racquetball, tennis ball, and baseball. Record these masses in your data table.
- **4.** Measure a 2-m distance on the floor and mark it with two pieces of masking tape.
- 5. Place the softball on one piece of tape.
- **6.** Use a stopwatch to time how long it takes the racquetball to slowly roll from the other piece of tape and hit the softball. Record this time in your data table.
- **7.** Measure and record the distance the racquetball moved the softball.
- **8.** Repeat steps 6–7, rolling the racquetball quickly.
- **9.** Repeat steps 6–7, rolling the tennis ball slowly, then quickly.
- **10.** Repeat steps 6–7, rolling the baseball slowly, then quickly.

# Analyze Your Data

- **1. Calculate** the momentum for each type of ball and action using the formula p = mv. Record your calculations in the data table.
- **2. Graph** the relationship between the momentum of each ball and the distance the softball was moved using a graph like the one shown.

# Momentum of Colliding Ball Do not write in this book. Momentum

**Distance Softball Moved and** 

# Conclude and Apply

- **1. Infer** from your graph how the distance the softball moves after each collision depends on the momentum of the ball that hits it.
- **2. Explain** how the motion of the balls after they collide obeys Newton's laws of motion.



**Compare** your graph with the graphs made by other students in your class. **Discuss** why the graphs might look different.







# TIME

# SCIENCE SCIENCE CAN CHANGE HISTORY

**THE COURSE OF HISTORY** 

# Newton and the Plague

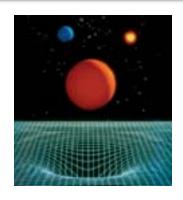
n 1665, the bubonic plague swept through England and other parts of Europe. Isaac Newton, then a 23-year-old university student, returned to his family's farm until Cambridge university reopened. To occupy his time, Newton made a list of 22 questions. During the next 18 months, Newton buried himself in the search for answers. And in that brief time, Newton developed calculus, the three laws of motion, and the universal law of gravitation!

# The Laws of Motion

Earlier philosophers thought that force was necessary to keep an object moving. By analyzing the data collected by Galileo and others, Newton realized that forces did not cause motion. Instead, forces cause a change in motion. Newton came to understand that force and acceleration were related and that objects exert equal and opposite forces on each other. Newton's three laws of



motion were able to explain how all things moved, from an apple falling from a tree to the motions of the moon and the planets, in terms of force, mass, and acceleration.



In Einstein's theory of general relativity, gravity is due to a distortion in space-time.

# What is gravity?

Using the calculus and data on the motion of the planets, Newton deduced the law of universal gravitation. This law enabled the force of gravity between any two objects to be calculated, if their masses and the distance between them were known.

Newton was able to show mathematically that the law of universal gravitation predicted that the planets' orbits should be ellipses, just as Johannes Kepler had discovered two generations earlier. The application of Newton's laws of motion and the law of universal gravitation also were able to explain phenomena such as tides, the motion of the moon and the planets, and the bulge at the Earth's equator.

# A Different View of Gravity

In 1916, Albert Einstein proposed a different model for gravity called the general theory of relativity. In Einstein's model, objects create distortions in space-time, like a bowling ball dropped on a sheet. What we see as the force of gravity is the motion of an object on distorted space-time. Today, Einstein's theory is used to help explain the nature of the big bang and the structure of the universe.

Isaac Newton was a university student when he developed the laws of motion.

Investigate Research how both Newton's law of gravitation and Einstein's general theory of relativity have been used to develop the current model of the universe.

For more information, visit gpescience.com

# **Reviewing Main Ideas**

# Section 1 The First Two Laws

- **1.** According to the first law of motion, the velocity of an object doesn't change unless an unbalanced net force acts on the object.
- **2.** Inertia is the tendency of an object to resist a change in its motion.
- **3.** The second law of motion states that a net force causes an object to accelerate in the direction of the net force and that the acceleration is given by

$$a = \frac{F_{\text{net}}}{m}$$



# Section 2 **Gravity**

- 1. Gravity is an attractive force between any two objects with mass. The gravitational force depends on the masses of the objects and the distance between them.
- **2.** The gravitational acceleration, g, near Earth's surface equals 9.8 m/s<sup>2</sup>. The force of gravity on an object with mass, m, is:

$$F = mg$$

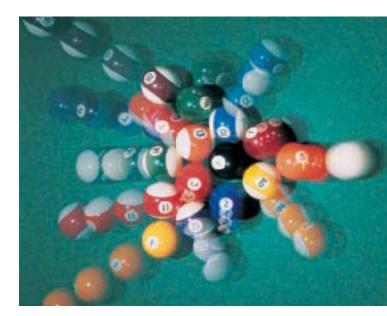
**3.** The weight of an object near Earth's surface is:

$$W = mg$$

- **4.** Projectiles travel in a curved path because of their horizontal motion and vertical acceleration due to gravity.
- **5.** The centripetal force is the net force on an object in circular motion and is directed toward the center of the circular path.

# Section 3 The Third Law of Motion

- 1. Newton's third law of motion states that for every action there is an equal and opposite reaction.
- **2.** The momentum of an object can be calculated by the equation p = mv.



**3.** When two objects collide, momentum can be conserved. Some of the momentum from one object is transferred to the other.

**FOLDABLES** Use the Foldable that you made at the beginning of this chapter to help you review the laws of motion.

# **Using Vocabulary**

centripetal acceleration p. 110 centripetal force p. 110 first law of motion p. 98 gravity p. 104 inertia p. 99 law of conservation of momentum p. 117 momentum p. 116 second law of motion p. 102 third law of motion p. 113 weight p. 106

Complete each statement using a word(s) from the vocabulary list above.

- **1.** The way in which objects exert forces on each other is described by \_\_\_\_\_.
- **2.** The \_\_\_\_\_ of an object depends on its mass and velocity.
- **3.** The \_\_\_\_\_\_ of an object is different on other planets in the solar system.
- **4.** When an object moves in a circular path, the net force is called a(n) \_\_\_\_\_.
- **5.** The attractive force between two objects that depends on their masses and the distance between them is \_\_\_\_\_\_.
- **6.** \_\_\_\_\_ relates the net force exerted on an object to its mass and acceleration.

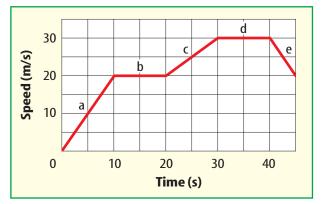
# **Checking Concepts**

Choose the best answer for each question.

- **7.** What is the gravitational force exerted on an object called?
  - **A)** centripetal force
- **c)** momentum
- **B)** friction
- **D)** weight
- **8.** Which of the following best describes why projectiles move in a curved path?
  - **A)** They have horizontal velocity and vertical acceleration.
  - **B)** They have momentum.
  - **c)** They have mass.
  - **D)** They have weight.

- **9.** Which of the following explains why astronauts seem weightless in orbit?
  - A) Earth's gravity is much less in orbit.
  - **B)** The space shuttle is in free fall.
  - **C)** The gravity of Earth and the Sun cancel.
  - **D)** The centripetal force on the shuttle balances Earth's gravity.
- **10.** Which of the following exerts the strongest gravitational force on you?
  - **A)** the Moon
- **c)** the Sun
- **B)** Earth
- **D)** this book

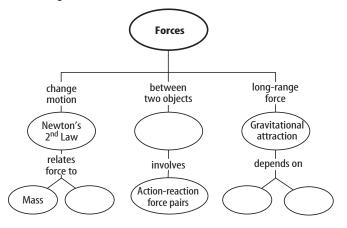
Use the graph below to answer question 11.



- **11.** The graph shows the speed of a car moving in a straight line. Over which segments are the forces on the car balanced?
  - **A)** A and C
- **c)** C and E
- **B)** B and D
- **D)** D only
- **12.** Which of the following is true about an object in free fall?
  - A) Its acceleration depends on its mass.
  - **B)** It has no inertia.
  - **c)** It pulls on Earth, and Earth pulls on it.
  - **D)** Its momentum is constant.
- **13.** The acceleration of an object is in the same direction as which of the following?
  - **A)** net force
- c) static friction
- **B)** air resistance
- **D)** gravity
- **14.** Which of the following is NOT a force?
  - A) weight
- **c)** momentum
- **B)** friction
- **D)** air resistance

# Interpreting Graphics

**15.** Copy and complete the following concept map on forces.



Use the table below to answer questions 16-18.

Time of Fall for Dropped Objects				
<b>Object</b>	Mass (g)	Time of Fall (s)		
А	5.0	2.0		
В	5.0	1.0		
С	30.0	0.5		
D	35.0	1.5		

**16.** If the objects in the data table above all fell the same distance, which object fell with the greatest average speed?

# **Thinking Critically**

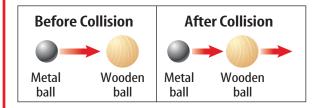
- **17. Describe** the forces acting on a softball after it leaves the pitcher's hand. Ignore the effects of air resistance.
- **18. Determine** the direction of the net force on a book sliding on a table if the book is slowing down.
- **19. Explain** whether there can be any forces acting on a car moving in a straight line with constant speed.

- **20. Explain** You pull a door open. If the force the door exerts on you is equal to the force you exert on the door, why don't you move?
- **21. Predict** Suppose you are standing on a bathroom scale next to a sink. How does the reading on the scale change if you push down on the sink?
- **22. Describe** the action and reaction force pairs involved when an object falls toward Earth. Ignore the effects of air resistance.

### **Applying Math**

- **23. Calculate Mass** Find your mass if a scale on Earth reads 650 N when you stand on it.
- **24. Calculate Acceleration of Gravity** You weigh yourself at the top of a high mountain and the scale reads 720 N. If your mass is 75 kg, what is the acceleration of gravity at your location?

Use the figure below to answer question 25.



- 25. Calculate Speed The 2-kg metal ball moving at a speed of 3 m/s strikes a 1-kg wooden ball that is at rest. After the collision, the speed of the metal ball is 1 m/s. Assuming momentum is conserved, what is the speed of the wooden ball?
- **26.** Calculate Mass Find the mass of a car that has a speed of 30 m/s and a momentum of 45,000 kg,m/s.
- **27. Calculate Sliding Friction** A box being pushed with a force of 85 N slides along the floor with a constant speed. What is the force of sliding friction on the box?

# chapter Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

### **Multiple Choice**

- **1.** The net force on an object moving with constant speed in circular motion is in which direction?
  - A. downward
  - **B.** opposite to the object's motion
  - **c.** toward the center of the circle
  - **D.** in the direction of the object's velocity

#### Use the table below to answer questions 2-4.

Object in Free Fall with Air Resistance			
Time (s)	Speed (m/s)		
0	0		
1	9.1		
2	15.1		
3	18.1		
4	19.3		
5	19.9		

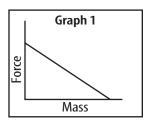
- **2.** Over which of the following time intervals is the acceleration of the object the greatest?
  - **A.** 0 s to 1 s
  - **B.** 1 s to 2 s
  - **c.** 4 s to 5 s
  - **D.** The acceleration is constant.

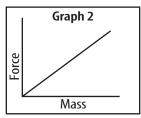
#### Test-Taking Tip

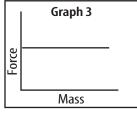
**Keep Track of Time** If you are taking a timed test, keep track of time. If you find you are spending too much time on a multiple-choice question, mark your best guess and move on.

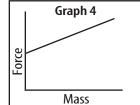
- **3.** Over which of the following time intervals is the net force on the object the smallest?
  - **A.** 0 s to 1 s
  - **B.** 1 s to 2 s
  - **c.** 4 s to 5 s
  - **D.** The force is constant.
- **4.** According to the trend in these data, which of the following values is most likely the speed of the object after falling for 6 s?
  - **A.** 26.7 m/s
  - **B.** 15.1 m/s
  - **c.** 20.1 m/s
  - **D.** 0 m/s
- **5.** Which of the following would cause the gravitational force between object A and object B to increase?
  - **A.** Decrease the distance between them.
  - **B.** Increase the distance between them.
  - **c.** Decrease the mass of object A.
  - **D.** Decrease the mass of both objects.

#### Use the graphs below to answer question 6.









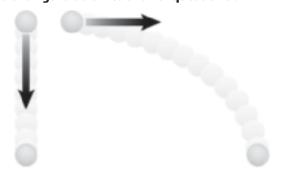
- **6.** Which of the graphs on the previous page shows how the force on an object changes if the mass increases and the acceleration stays constant?
  - A. Graph 1
  - **B.** Graph 2
  - **c.** Graph 3
  - **D.** Graph 4

#### **Gridded Response**

- 7. You are pushing a 30-kg wooden crate across the floor. The force of sliding friction on the crate is 90 N. How much force, in newtons, must you exert on the crate to keep it moving with a constant velocity?
- **8.** A skydiver with a mass of 60 kg jumps from an airplane. Five seconds after jumping, the force of air resistance on the skydiver is 300 N. What is the skydiver's acceleration in m/s<sup>2</sup> five seconds after jumping?

# **Short Response**

Use the figure below to answer question 9.



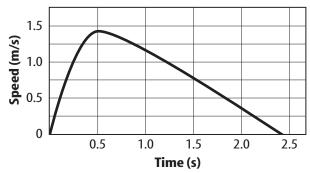
- 9. Two balls are at the same height. One ball is dropped and the other initially moves horizontally, as shown in the figure.

  After 1 s, which ball has fallen the greatest vertical distance?
- **10.** How does the acceleration of gravity 5,000 km above Earth's surface compare with the acceleration of gravity at Earth's surface?

### Extended Response

Use the graph below to answer question 11.





- 11. The graph above shows the how the speed of a book changes as it slides across a table. Over what time interval is the net force on the book in the opposite direction of the book's motion?
- 12. When the space shuttle is launched from Earth, the rocket engines burn fuel and apply a constant force on the shuttle until they burn out. Explain why the shuttles acceleration increases while the rocket engines are burning fuel.

# chapter



### BIG (Idea

Every change that occurs requires energy.

#### **5.1 The Nature of Energy**

MAIN (Idea There are different forms of energy, including potential energy and kinetic energy.

# **5.2 Conservation of Energy**

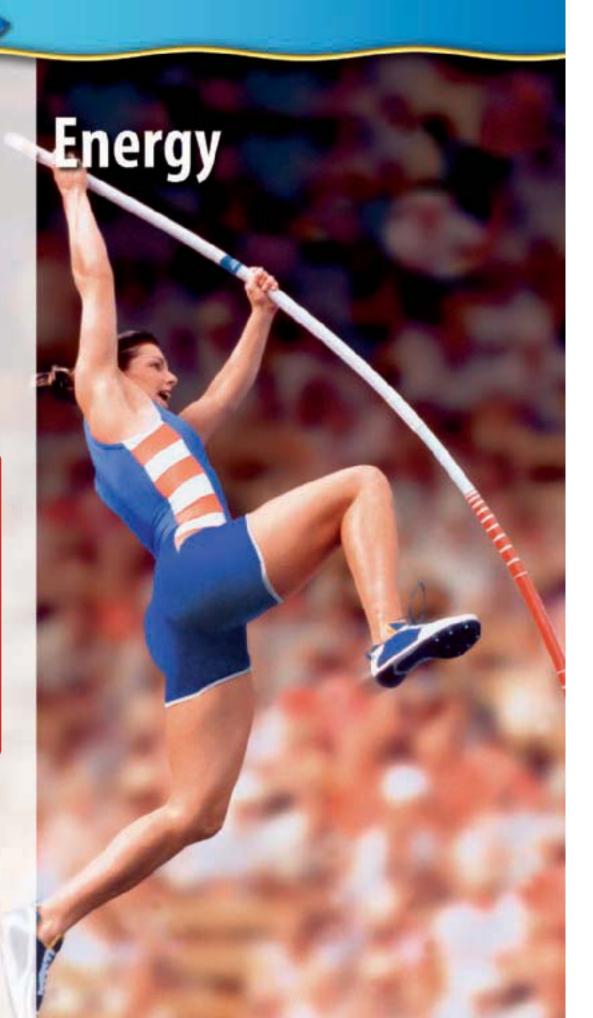
MAIN (Idea Energy cannot be created or destroyed, but only can change from one form to another.

# A Big Lift

How does this pole vaulter go from standing at the end of a runway to climbing through the air? The answer is energy. During her vault, energy originally stored in her muscles is converted into other forms of energy that enable her to soar.

#### **Science Journal**

Which takes more energy: walking up stairs or taking an escalator? Explain your reasoning.



# **Start-Up Activities**



# **Energy Conversions**

One of the most useful inventions of the nineteenth century was the electric lightbulb. Being able to light up the dark has enabled people to work and play longer. A lightbulb converts electrical energy to heat energy and light, another form of energy. The following lab shows how electrical energy is converted into other forms of energy.



**WARNING:** Steel wool can become hot—connect to battery only for a brief time.

- 1. Complete the safety form.
- Obtain two D-cell batteries, tape, metal tongs, two non-coated paper clips, and some steel wool. Separate the steel wool into thin strands and straighten the paper clips.
- 3. Tape the batteries together and then tape one end of each paper clip to the battery terminals.
- 4. While holding the steel wool with the tongs, briefly complete the circuit by placing the steel wool in contact with both the paper clip ends.
- 5. Think Critically In your Science Journal, describe what happened to the steel wool. What changes did you observe?



Preview this chapter's content and activities at gpescience.com

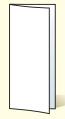


**Energy** Make the following Foldable to help you identify what you already know, what

you want to know, and what you learned about energy.

STEP 1

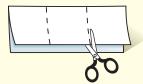
Fold a sheet of paper vertically from side to side. Make the front edge about 1 cm shorter than the back edge.



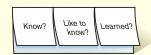
Turn lengthwise and fold into thirds.



STEP 3 Unfold and cut only the top layer along both folds to make three tabs.



STEP 4 Label each tab as shown.



**Question** Before you read the chapter, write what you already know about energy under the left tab of your Foldable, and write questions about what you'd like to know under the center tab. After you read the chapter, list what you learned under the right tab.

# The Nature of Energy

# **Reading Guide**

# What You'll Learn

- Distinguish between kinetic and potential energy.
- Calculate kinetic energy.
- **Describe** different forms of potential energy.
- **Calculate** gravitational potential energy.

# Why It's Important

All of the changes that occur around you every day involve the conversion of energy from one form to another.

#### Review Vocabulary

**gravity:** the attractive force between any two objects that have mass

#### New Vocabulary

- energy
- kinetic energy
- ioule
- potential energy
- elastic potential energy
- chemical potential energy
- gravitational potential energy

# What is energy?

Wherever you are sitting as you read this, changes are taking place—lightbulbs are heating the air around them, the wind might be rustling leaves, or sunlight might be glaring off a nearby window. Even you are changing as you breathe, blink, or shift position in your seat.

Every change that occurs—large or small—involves energy. Imagine a baseball flying through the air. It hits a window, causing the glass to break as shown in **Figure 1.** The window changed from a solid sheet of glass to a number of broken pieces. The moving baseball caused this change—a moving

> baseball has energy. Even when you comb your hair or walk from one class to another, energy is involved.

> **Energy and Work** In science, energy is defined as the ability to do work. Work is done when a force causes something to move. The ball in **Figure 1** does work on the window when it exerts a force on the glass and causes it to break. Energy also can be defined as the ability to cause change. When work is done, something moves and a change occurs. When work is done and a change occurs, energy moves from place to place or changes from one form to another.

**Figure 1** The baseball caused changes to occur when it hit the window.

**Describe** the changes that are occurring.





**Different Forms of Energy** 

Turn on an electric light, and a dark room becomes bright. Turn on your CD player, and sound comes through your headphones.

In both situations, energy moves from one place to another. These changes are different from each other, and differ from the baseball shattering the window in **Figure 1.** This is because energy has several different forms—electrical, chemical, radiant, and thermal.

**Figure 2** shows some examples of everyday situations which involve forms of energy. Is the chemical energy stored in food the same as the energy that comes from the Sun or the energy stored in gasoline? Radiant energy from the Sun travels a vast distance through space to Earth, warming the planet and providing energy that enables green plants to grow. When you make toast in the morning, you are using electrical energy. In short, energy plays a role in every activity that you do.

Reading Check What are some different forms of energy?

**An Energy Analogy** Money can be used in an analogy to help you understand energy. If you have \$100, you could store it in a variety of forms—cash in your wallet, a bank account, travelers' checks, or gold or silver coins. You could transfer that money to different forms. You could deposit your cash into a bank account or trade the cash for gold. Regardless of its form, money is money. The same is true for energy. Energy from the Sun that warms you and energy from the food that you eat are only different forms of the same thing.

**Figure 2** Energy can be stored and it can move from place to place. **Infer** which materials are storing chemical energy.



#### **Topic: Glacier Flow**

Visit **gpescience.com** for Web links to information about the speeds at which glaciers flow.

**Activity** For the five fastest glaciers, calculate the kinetic energy a 1-kg block of ice in each glacier would have.

# **Kinetic Energy**

When you think of energy, you might think of action—or objects in motion—like the baseball that shatters a window. An object in motion does have energy. **Kinetic energy** is the energy a moving object has because of its motion. The kinetic energy of a moving object depends on the object's mass and its speed.

#### **Kinetic Energy Equation**

**kinetic energy** (in joules) =  $\frac{1}{2}$  mass (in kg)  $\times$  [speed (in m/s)]<sup>2</sup>

$$\mathbf{KE} = \frac{1}{2} \mathbf{m} \mathbf{v}^2$$

The SI unit of energy is the **joule**, abbreviated J. If you dropped a softball from a height of about 0.5 m, it would have a kinetic energy of about one joule before it hit the floor.

# **Applying Math**

# **Solve a Simple Equation**

**KINETIC ENERGY** A jogger whose mass is 60 kg is moving at a speed of 3 m/s. What is the jogger's kinetic energy?

#### **IDENTIFY** known values and the unknown value

Identify the known values:

a jogger whose mass is 60 kg m = 60 kg

is moving at a speed of 3 m/s v = 3 m/s

Identify the unknown value:

What is the jogger's kinetic energy? KE = ? J

# **SOLVE** the problem

Substitute the known values m = 60 kg and v = 3 m/s into the kinetic energy equation:

$$KE = \frac{1}{2}mv^2 = \frac{1}{2} (60 \text{ kg})(3 \text{ m/s})^2 = \frac{1}{2} (60)(9) \text{ kg m}^2/\text{s}^2 = 270 \text{ J}$$

#### **CHECK** your answer

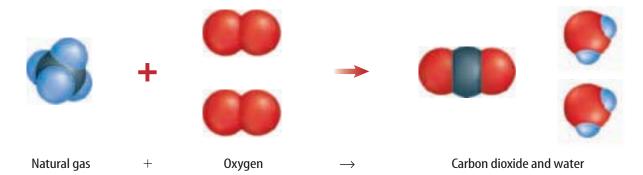
Does your answer seem reasonable? Check your answer by dividing the kinetic energy you calculate by the square of the given velocity, and then multiplying by 2. The result should be the mass given in the problem.

# **Practice Problems**

- **1.** What is the kinetic energy of a baseball moving at a speed of 40 m/s if the baseball has a mass of 0.15 kg?
- 2. A car moving at a speed of 20 m/s has a kinteic energy of 300,000 J. What is the car's mass?
- 3. A sprinter has a mass of 80 kg and a kinetic energy of 4,000 J. What is the sprinter's speed?

For more practice problems go to page 879, and visit Math Practice at gpescience.com.

**Figure 3** As natural gas burns, it combines with oxygen to form carbon dioxide and water. In this chemical reaction, chemical potential energy is released.



# **Potential Energy**

Energy doesn't have to involve motion. Even motionless objects can have energy. This energy is stored in the object. Therefore, the object has potential to cause change. A hanging apple in a tree has stored energy. When the apple falls to the ground, a change occurs. Because the apple has the ability to cause change, it has energy. The hanging apple has energy because of its position above Earth's surface. Stored energy due to position is called **potential energy**. If the apple stays in the tree, it will keep the stored energy due to its height above the ground. If it falls, that stored energy of position is converted to energy of motion.

**Elastic Potential Energy** Energy can be stored in other ways, too. If you stretch a rubber band and let it go, it sails across the room. As it flies through the air, it has kinetic energy due to its motion. Where did this kinetic energy come from? Just as the apple hanging in the tree had potential energy, the stretched rubber band had energy stored as elastic potential energy. **Elastic potential energy** is energy stored by something that can stretch or compress, such as a rubber band or spring.

**Chemical Potential Energy** The cereal you eat for breakfast and the sandwich you eat at lunch also contain stored energy. Gasoline stores energy in the same way as food stores energy—in the chemical bonds between atoms. Energy stored in chemical bonds is **chemical potential energy. Figure 3** shows a molecule of natural gas. Energy is stored in the bonds that hold the carbon and hydrogen atoms together and is released when the gas is burned.



How is elastic potential energy different from chemical potential energy?



# Interpreting Data from a Slingshot

#### 

- **1.** Complete the safety form.
- 2. Using two fingers, carefully stretch a **rubber band** on a table until it has no slack.
- **3.** Place a **nickel** on the table, slightly touching the midpoint of the rubber band.
- **4.** Push the nickel back 0.5 cm into the rubber band and release. Measure the distance the nickel travels.
- **5.** Repeat step 4, each time pushing the nickel back an additional 0.5 cm.

#### **Analysis**

- 1. How did the takeoff speed of the nickel seem to change relative to the distance that you stretched the rubber band?
- 2. What does this imply about the kinetic energy of the nickel?



The Myth of Sisyphus In Greek mythology, a king named Sisyphus angered the gods by attempting to delay death. As punishment, he was doomed for eternity to endlessly roll a huge stone up a hill, only to have it roll back to the bottom again. Explain what caused the potential energy of the stone to change as it moved up and down the hill.

**Gravitational Potential Energy** Anything that can fall has stored energy called gravitational potential energy. **Gravitational potential energy** (GPE) is energy stored by objects due to their position above Earth's surface. The GPE of an object depends on the object's mass and height above the ground. Gravitational potential energy can be calculated from the following equation.

#### **Gravitational Potential Energy Equation**

gravitational potential energy (J) =
mass (kg)  $\times$  acceleration due to gravity (m/s<sup>2</sup>)  $\times$  height (m) GPE = mgh

On Earth, the acceleration due to gravity is  $9.8 \text{ m/s}^2$  and has the symbol g. Like all forms of energy, gravitational potential energy is measured in joules.

# **Applying Math**

### **Solve a Simple Equation**

**GRAVITATIONAL POTENTIAL ENERGY** What is the gravitational potential energy of a ceiling fan that has a mass of 7 kg and is 4 m above the ground?

**IDENTIFY** known values and the unknown value

Identify the known values:

has a mass of 7 kg 
$$means$$
  $m = 7 kg$ 

is 4 m above the ground 
$$means$$
  $h = 4 m$ 

Identify the unknown value:

what is the gravitational potential energy GPE = ? J

SOLVE the problem

Substitute the known values m = 7 kg, h = 4 m, and g = 9.8 m/s<sup>2</sup> into the gravitational potential energy equation:

$$GPE = mgh = (7 \text{ kg})(9.8 \text{ m/s}^2)(4 \text{ m}) = (274) \text{ kg m}^2/\text{s}^2 = 274 \text{ J}$$

**CHECK** your answer

Does your answer seem reasonable? Check your answer by dividing the gravitational potential energy you calculate by the given mass, and then divide by 9.8 m/s<sup>2</sup>. The result should be the height given in the problem.

#### **Practice Problems**

- 1. Find the height of a baseball with a mass of 0.15 kg that has a GPE of 73.5 J.
- 2. Find the GPE of a coffee mug with a mass of 0.3 kg on a 1-m high counter top.
- 3. What is the mass of a hiker 200 m above the ground if her GPE is 117,600 J? For more practice problems go to page 879, and visit Math Practice at gpescience.com.

**Changing GPE** Look at the objects in the bookcase in **Figure 4.** Which of these objects has the most gravitational potential energy? According to the equation for gravitational potential energy, the GPE of an object can be increased by increasing its height above the ground. If two objects are at the same height, then the object with the larger mass has more gravitational potential energy.

In **Figure 4**, suppose the green vase on the lower shelf and the blue vase on the upper shelf have the same mass. Then the blue vase on the upper shelf has more gravitational potential energy because it is higher above the ground.

Imagine what would happen if the two vases were to fall. As they fall and begin moving, they have kinetic energy as well as gravitational potential energy. As the vases get closer to the ground, their gravitational potential energy decreases. At the same time, they are moving faster, so their kinetic energy increases. The vase that was higher above the floor has fallen a greater distance. As a result, the vase that initially had more gravitational potential energy will be moving faster and have more kinetic energy when it hits the floor.



**Figure 4** An object's gravitational potential energy increases as its height increases.

# section

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# Summary

#### **Energy**

- Energy is the ability to cause change.
- Forms of energy include electrical, chemical, thermal, and radiant energy.

# **Kinetic Energy**

- Kinetic energy is the energy a moving object has because of its motion.
- The kinetic energy of a moving object can be calculated from this equation:

$$KE = \frac{1}{2} mv^2$$

#### **Potential Energy**

- Potential energy is stored energy due to the position of an object.
- Different forms of potential energy include elastic potential energy, chemical potential energy, and gravitational potential energy.
- Gravitational potential energy can be calculated from this equation:

$$GPE = mgh$$

#### **Self Check**

**1. Explain** whether an object can have kinetic energy and potential energy at the same time.

review

- Describe three situations in which the gravitational potential energy of an object changes.
- **3. Explain** how the kinetic energy of a truck could be increased without increasing the truck's speed.
- **4. Think Critically** The different molecules that make up the air in a room have, on average, the same kinetic energy. How does the speed of the different air molecules depend on their masses?

# **Applying Math**

- **5. Calculate Kinetic Energy** Find the kinetic energy of a ball with a mass of 0.06 kg moving at 50 m/s.
- **6. Use Ratios** A boulder on top of a cliff has potential energy of 8,800 J and twice the mass of a boulder next to it. What is the GPE of the smaller boulder?
- **7. Calculate GPE** An 80-kg diver jumps from a 10-m high platform. What is the gravitational potential energy of the diver halfway down?



# B@uncing Balls

What happens when you drop a ball onto a hard, flat surface? It starts with potential energy. It bounces up and down until it finally comes to a rest. Where did the energy go?

# 🔘 Real-World Problem

Why do bouncing balls stop bouncing?

#### Goals

- Identify the forms of energy observed in a bouncing ball.
- Infer why the ball stops bouncing.

#### Materials

tennis hall masking tape rubber ball cardboard box balance \*shoe box meterstick \*Alternate materials

# Safety Precautions



# Procedure

- 1. Complete the safety form.
- 2. Measure the mass of the two balls.
- **3.** Have a partner drop one ball from 1 m. Measure how high the ball bounced. Repeat this two more times so you can calculate an average bounce height. Record your values on the data table.
- **4.** Repeat step 3 for the other ball.
- **5. Predict** whether the balls would bounce higher or lower if they were dropped onto the cardboard box. Design an experiment to measure how high the balls would bounce off the surface of a cardboard box.

Bounce Height				
Type of Ball	Surface	Trial	Height (cm)	
Tennis	Floor	1		
Tennis	Floor	2		
Tennis	Floor	3		
Rubber	Floor	1		
Rubber	Floor	2		
Rubber	Floor	3		
Tennis	Box	1		

# Conclude and Apply

- **1. Calculate** the gravitational potential energy of each ball before dropping it.
- **2. Calculate** the average bounce height for the three trials under each condition. Describe your observations.
- **3. Compare** the bounce heights of the balls dropped on a cardboard box with the bounce heights of the balls dropped on the floor. Hint: Did you observe any movement of the box when the balls bounced?
- **4. Explain** why the balls bounced to different heights, using the concept of elastic potential energy.

# ommunicating Your Data

Meet with three other lab teams and compare average bounce heights for the tennis ball on the floor. Discuss why your results might differ. For more help, refer to the Science Skill Handbook.

# **Conservation of Energy**

# **Reading Guide**

# *What* You'll Learn

- **Describe** how energy can be transformed from one form to another.
- **Explain** how the mechanical energy of a system is the sum of the kinetic and potential energy.
- **Discuss** the law of conservation of energy.

# Why It's Important

All the energy transformations that occur inside you and around you obey the law of conservation of energy.

#### Review Vocabulary

**friction:** a force that opposes the sliding motion of two surfaces that are touching each other

#### **New Vocabulary**

- mechanical energy
- law of conservation of energy

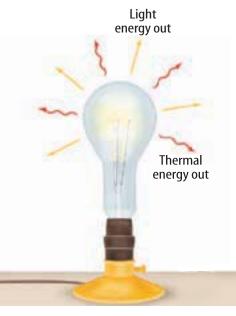
# **Changing Forms of Energy**

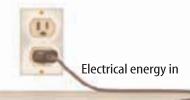
Unless you were talking about potential energy, you probably wouldn't think of the book on top of a bookshelf as having much to do with energy—until it fell. You'd be more likely to think of energy as race cars roar past, or as your body uses energy from food to help it move, or as the Sun warms your skin on a summer day. These situations involve energy changing from one form to another form.

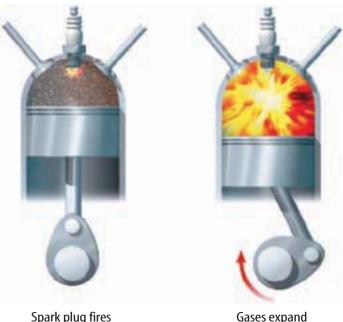
Transforming Electrical Energy You use many devices every day that convert one form of energy to other forms. For example, you might be reading this page in a room lit by lightbulbs. The lightbulbs transform electrical energy into light so you can see. The warmth you feel around the bulb is evidence that some of that electrical energy is transformed into thermal energy, as illustrated in **Figure 5.** What other devices have you used today that make use of electrical energy? You might have been awakened by an alarm clock, styled your hair, made toast, listened to music, or played a video game. What form or forms of energy is electrical energy converted to in these examples?

**Figure 5** A lightbulb is a device that transforms electrical energy into light energy and thermal energy.

**Identify** *other devices that convert* electrical energy to thermal energy.







Spark plug fires

When a spark plug fires in an engine, chemical potential energy is converted into thermal energy.

**Figure 6** In the engine of a car, several energy conversions occur.

As the hot gases expand, thermal energy is converted

into kinetic energy.

**Transforming** Chemical **Energy** Fuel stores energy in the form of chemical potential energy. For example, the car or bus that might have brought you to school this morning probably uses gasoline as a fuel. The engine transforms the chemical potential energy stored in gasoline molecules into the kinetic energy of a moving car or bus. Several energy conversions occur in this process, as shown in **Figure 6.** An electric spark ignites a small amount of fuel. Igniting the fuel changes chemical energy to thermal energy. The thermal energy causes gases to expand and move parts of the engine, producing kinetic energy.

Some energy transformations are less obvious because they do not result in visible motion, sound, heat, or light. Every green plant you see converts light energy from the Sun into energy stored in chemical bonds in the plant. If you eat an ear of corn, the chemical potential energy in the corn is transformed into other forms of energy by your body.

# **Conversions Between Kinetic** and Potential Energy

You have experienced many situations that involve conversions between potential and kinetic energy. Systems such as bicycles, roller coasters, and swings can be described in terms of potential and kinetic energy. Even launching a rubber band or using a bow and arrow involves converting potential energy into kinetic energy. To understand the energy conversions that occur, it is helpful to identify the mechanical energy of a system. **Mechanical energy** is the total amount of potential and kinetic energy in a system and can be expressed by this equation.

# mechanical energy = potential energy + kinetic energy

In other words, mechanical energy is energy due to the position and the motion of an object or the objects in a system. What happens to the mechanical energy of an object as potential and kinetic energy are converted into each other?

**Falling Objects** Standing under an apple tree can be hazardous. An apple on a tree, like the one in **Figure 7**, has gravitational potential energy due to Earth pulling down on it. The apple does not have kinetic energy while it hangs from the tree. However, the instant the apple comes loose from the tree, it accelerates due to gravity. As it falls, it loses height so its gravitational potential energy decreases. This potential energy is transformed into kinetic energy as the speed of the apple increases.

Look back at the equation for mechanical energy. If the potential energy is being converted into kinetic energy, then the mechanical energy of the apple doesn't change as it falls. The potential energy that the apple loses is gained back as kinetic energy. The form of energy changes, but the total amount of energy remains the same.



What happens to the mechanical energy of the apple as it falls from the tree?

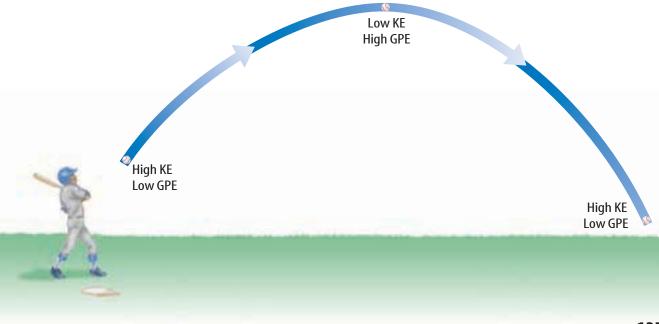
Energy Transformations in Projectile Motion Energy transformations also occur during projectile motion when an object moves in a curved path. Look at Figure 8. When the ball leaves the bat, it has mostly kinetic energy. As the ball rises, its speed decreases, so its kinetic energy must decrease, too. However, the ball's gravitational potential energy increases as it goes higher. At its highest point, the baseball has the maximum amount of gravitational potential energy. The only kinetic energy it has at this point is due to its forward motion. Then, as the baseball falls, gravitational potential energy decreases while kinetic energy increases as the ball moves faster. However, the mechanical energy of the ball remains constant as it rises and falls.



**Figure 7** Objects that can fall have gravitational potential energy.

**Apply** What objects around you have gravitational potential energy?

**Figure 8** Kinetic energy and gravitational potential energy are converted into each other as the ball rises and falls.



# **NATIONAL** GEOGRAPHIC VISUALIZING ENERGY TRANSFORMATIONS

KE increasing

# Figure 9

ride on a swing illustrates how kinetic energy changes to potential energy and back to kinetic energy again. The diagram at right shows four stages of the swing's motion. Although it changes from one form to another, the total PE = Maximum energy remains the same. KE = 0

B As she falls toward the At the rider's bottom of the path, the highest point, her rider accelerates and gains potential energy kinetic energy. Because the is at a maximum rider is not as high above and her kinetic the ground, her potential energy is zero. energy decreases.

The rider, rising toward the opposite side, begins to slow down and lose kinetic energy. As she gains

PE = Minimum

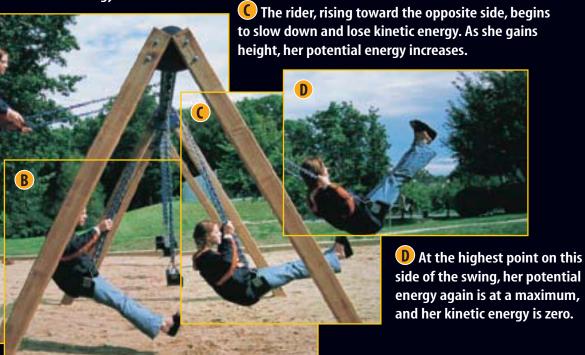
**KE** = Maximum

**KE** ≠ Kinetic Energy

PE = Potential Energy

PE = Maximum

KE = 0



**Energy Transformations in a Swing** When you ride on a swing, like the one shown in **Figure 9**, part of the fun is the feeling of almost falling as you drop from the highest point to the lowest point of the swing's path. Think about energy conservation to analyze such a ride.

The ride starts with a push that gets you moving, giving you kinetic energy. As the swing rises, you lose speed but gain height. In energy terms, kinetic energy changes to gravitational potential energy. At the top of your path, potential energy is at its greatest. Then, as the swing accelerates downward, potential energy changes to kinetic energy. At the bottom of each swing, the kinetic energy is at its greatest and the potential energy is at its minimum. As you swing back and forth, energy continually converts from kinetic to potential and back to kinetic. What happens to your mechanical energy as you swing?

# The Law of Conservation of Energy

When a ball is thrown into the air or a swing moves back and forth, kinetic and potential energy are constantly changing as the object speeds up and slows down. However, mechanical energy stays constant. Kinetic and potential energy simply change forms and no energy is destroyed.

This is always true. Energy can change from one form to another, but the total amount of energy never changes. Even when energy changes form from electrical to thermal and other energy forms as in the hair dryer shown in **Figure 10**, energy is never destroyed. Another way to say this is that energy is conserved. This principle is recognized as a law of nature. The law of conservation of energy states that energy cannot be created or destroyed. On a large scale, this law means that the total amount of energy in the universe does not change.

Reading Check

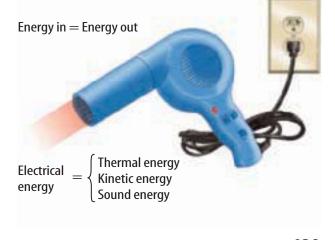
What law states that the total amount of energy never changes?

Conserving Resources You might have heard about energy conservation or been asked to conserve energy. These ideas are related to reducing the demand for electricity and gasoline, which lowers the consumption of energy resources such as coal and fuel oil. The law of conservation of energy, on the other hand, is a universal principle that describes what happens to energy as it is transferred from one object to another or as it is transformed.

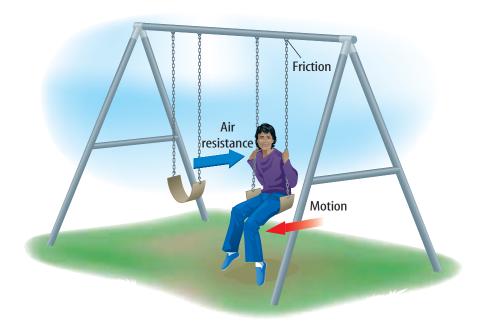


**Energy and the Food** Chain One way energy enters ecosystems is when green plants transform radiant energy from the Sun into chemical potential energy in the form of food. Energy moves through the food chain as animals that eat plants are eaten by other animals. Some energy leaves the food chain, such as when living organisms release thermal energy to the environment. Diagram a simple biological food chain showing energy conservation.

Figure 10 The law of conservation of energy requires that the total amount of energy going into a hair dryer must equal the total amount of energy coming out of the hair dryer.



**Figure 11** In a swing, mechanical energy is transformed into thermal energy because of friction and air resistance. **Infer** how the kinetic and potential energy of the swing change with time.





# **Transforming Energy** in a Paper Clip

#### 

- **1.** Complete the safety form.
- Straighten a paper clip.
   While holding the ends,
   touch the paper clip to
   the skin just below your
   lower lip. Note whether
   the paper clip feels warm,
   cool, or about room
   temperature.
- 3. Quickly bend the paper clip back and forth five times. Touch it below your lower lip again. Note whether the paper clip feels warmer or cooler than before.

#### **Analysis**

- What happened to the temperature of the paper clip? Why?
- 2. Describe the energy conversions that take place as you bend the paper clip.

**Is energy always conserved?** You might be able to think of situations where it seems as though energy is not conserved. For example, while coasting along a flat road on a bicycle, you know that you will eventually stop if you don't pedal. If energy is conserved, why wouldn't your kinetic energy stay constant so that you would coast forever? In many situations, it might seem that energy is destroyed or created. Sometimes it is hard to see the law of conservation of energy at work.

**The Effect of Friction** You know from experience that if you don't continue to pump a swing or be pushed by somebody else, your arcs will become lower and you eventually will stop swinging. In other words, the mechanical (kinetic and potential) energy of the swing seems to decrease, as if the energy were being destroyed. Is this a violation of the law of conservation of energy?

It can't be—it's the law! If the energy of the swing decreases, then the energy of some other object must increase by an equal amount to keep the total amount of energy the same. What could this other object be that experiences an energy increase? To answer this, you need to think about friction. With every movement, the swing's ropes or chains rub on their hooks and air pushes on the rider, as illustrated in **Figure 11.** Friction and air resistance cause some of the mechanical energy of the swing to change to thermal energy. With every pass of the swing, the temperature of the hooks and the air increases a little, so the mechanical energy of the swing is not destroyed. Rather, it is transformed into thermal energy. The total amount of energy always stays the same.

**Converting Mass into Energy** You might have wondered how the Sun unleashes enough energy to light and warm Earth from so far away. A special kind of energy conversion—nuclear fusion—takes place in the Sun and other stars. During this process a small amount of mass is transformed into a tremendous amount of energy. An example of a nuclear fusion reaction is shown in **Figure 12.** In the reaction shown here, the nuclei of the hydrogen isotopes deuterium and tritium undergo fusion.

**Nuclear Fission** Another process involving the nuclei of atoms, called nuclear fission, converts a small amount of mass into enormous quantities of energy. In this process, nuclei do not fuse—they are broken apart, as shown in **Figure 12.** In either process, fusion or fission, mass is converted to energy. In processes involving nuclear fission and fusion, the total amount of energy is still conserved if the energy content of the masses involved are included. Then the total energy before the reaction is equal to the total energy after the reaction, as required by the law of conservation of energy. The process of nuclear fission is used by nuclear power plants to generate electrical energy.



#### **Topic: Nuclear Fusion**

Visit gpescience.com for Web links to information about using nuclear fusion as a source of energy in electric power plants.

**Activity** Make a table listing the advantages and disadvantages of using nuclear fusion as an energy source.

**Figure 12** Mass is converted to energy in the processes of fusion and fission.

# **Nuclear fusion Nuclear fission** energy Radiant energy Sr

Mass  ${}_{1}^{2}H + Mass {}_{1}^{3}H > Mass He + Mass neutron$ 

In this fusion reaction, the combined mass of the two hydrogen nuclei is greater than the mass of the helium nucleus, He, and the neutron.

Mass U + Mass neutron > Mass Xe + Mass Sr + Mass neutrons

In nuclear fission, the mass of the large nucleus on the left is greater than the combined mass of the other two nuclei and the neutrons.

# The Human Body—Balancing the Energy Equation

What forms of energy discussed in this chapter can you find in the human body? With your right hand, reach up and feel your left shoulder. With that simple action, stored potential energy within your body was converted to the kinetic energy of your moving arm. Did your shoulder feel warm to your hand? Some of the chemical potential energy stored in your body is used to maintain a nearly constant internal temperature. A portion of this energy also is converted to the excess heat that your body gives off to its surroundings. Even the people shown standing in **Figure 13** require energy conversions to stand still.

**Figure 13** The runners convert the energy stored in their bodies more rapidly than the spectators do. **Calculate** *Use Table 1 to calculate how long a person would need to stand to burn as much energy as a runner burns in 1 h.* 

Energy Conversions in Your Body The complex chemical and physical processes going on in your body also obey the law of conservation of energy. Your body stores energy in the form of fat and other chemical compounds. This chemical potential energy is used to fuel the processes that keep you alive, such as making your heart beat and digesting the food you eat. Your body also converts this energy to heat that is transferred to your surroundings, and you use this energy to make your body move. Table 1 shows the amount of energy used in doing various activities. To maintain a healthy weight, you must have a proper balance between energy contained in the food you eat and the energy your body uses.



Food Energy Your body has been busy

breaking down your breakfast into molecules that can be used as fuel. The chemical potential energy in these molecules supplies the cells in your body with the energy they need to function. Your body also can use the chemical potential energy stored in fat for its energy needs. The food Calorie (C) is a unit used by nutritionists to measure how much energy you get from various foods-1 C is equivalent to about 4,184 J. Every gram of fat a person consumes can supply 9 C of energy. Carbohydrates and proteins each supply about 4 C of energy per gram.

Look at the labels on food packages. They provide information about the Calories contained in a serving, as well as the amounts of protein, fat, and carbohydrates.

Table 1 Calories Used in One Hour				
Type of Activity	Body Frames Small Medium Large			
Sleeping	48	56	64	
Sitting	72	84	96	
Eating	84	98	112	
Standing	96	112	123	
Walking	180	210	240	
Playing tennis	380	420	460	
Bicycling (fast)	500	600	700	
Running	700	850	1,000	

# section

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### Summary

#### **Energy Transformations**

- Energy can be transformed from one form to another.
- Devices such as lightbulbs, hair dryers, and automobile engines convert one form of energy into other forms.
- The mechanical energy of a system is the sum of the kinetic and potential energy in the system:  $mechanical\ energy = KE + PE$
- In falling, projectile motion, and swings, kinetic and potential energy are transformed into each other and the mechanical energy doesn't change.

#### The Law of Conservation of Energy

- According to the law of conservation of energy, energy cannot be created or destroyed.
- Friction converts mechanical energy into thermal energy.
- Fission and fusion are nuclear reactions that convert a small amount of mass in a nucleus into an enormous amount of energy.

#### Self Check

- 1. Explain how friction affects the mechanical energy of a system.
- 2. **Describe** the energy transformations that occur as you coast down a long hill on a bicycle and apply the brakes, causing the brake pads and bicycle rims to feel warm.
- 3. Explain how energy is conserved when nuclear fission or fusion occurs.
- **4. Think Critically** A roller coaster is at the top of a hill and rolls to the top of a lower hill. If mechanical energy is conserved, on the top of which hill is the kinetic energy of the roller coaster larger?

# **Applying Math**

- 5. Calculate Kinetic Energy The potential energy of a swing is 200 J at its highest point and 50 J at its lowest point. If mechanical energy is conserved, what is the kinetic energy of the swing at its lowest point?
- **6. Calculate Thermal Energy** The mechanical energy of a bicycle at the top of a hill is 6,000 J. The bicycle stops at the bottom of the hill by applying the brakes. If the potential energy of the bicycle is 2,000 J at the bottom of the hill, how much thermal energy was produced?



# **Design Your Own**

# Swing ing Energy

#### Goals

- Construct a pendulum to compare the exchange of potential and kinetic energy when a swing is interrupted.
- Measure the starting and ending heights of the pendulum.

#### **Possible Materials**

ring stand
test-tube clamp
support-rod clamp, right
angle
30-cm support rod
2-hole, medium rubber
stopper
string (1 m)
metersticks (2)
graph paper

# **Safety Precautions**



WARNING: Be sure the base is heavy enough or well anchored so that the apparatus will not tip over.

# Real-World Problem -

Imagine yourself swinging on a swing. What would happen if a friend grabbed the swing's chains as you passed the lowest point? Would you come to a complete stop or continue rising to your previous maximum height? How does the motion and maximum height reached by a swing change if the swing is interrupted?

# Form a Hypothesis –

Examine the diagram on this page. How is it similar to the situation in the introductory paragraph? An object that is suspended so that it can swing back and forth is called a pendulum. Hypothesize what will happen to the pendulum's motion and final height if its swing is interrupted.



# Using Scientific Methods

# Test Your Hypothesis

#### Make a Plan

- 1. Complete the safety form.
- **2.** As a group, write your hypothesis and list the steps that you will take to test it. Be specific. Also list the materials you will need.
- **3. Design** a data table and place it in your Science Journal.
- **4.** Set up an apparatus similar to the one shown in the diagram.
- **5. Devise** a way to measure the starting and ending heights of the stopper. Record your starting and ending heights in a data table. This will be your control.
- **6.** Be sure you test your swing, starting it above and below the height of the cross arm. How many times should you repeat each starting point?

#### **Follow Your Plan**

- 1. Make sure your teacher approves your plan before you start.
- **2.** Carry out the approved experiment as planned.
- **3.** While the experiment is going on, write any observations that you make and complete the data table in your Science Journal.

# Analyze Your Data

- 1. When the stopper is released from the same height as the cross arm, is the ending height of the stopper exactly the same as its starting height? Use your data to support your answer.
- **2. Analyze** the energy transfers. At what point along a single swing does the stopper have the greatest kinetic energy? The greatest potential energy?

# Conclude and Apply

- 1. Explain Do the results support your hypothesis?
- **2. Compare** the starting heights to the ending heights of the stopper. Is there a pattern? Can you account for the observed behavior?
- **3. Discuss** Do your results support the law of conservation of energy? Why or why not?
- **4. Infer** What happens if the mass of the stopper is increased? Test it.



**Compare** your conclusions with those of the other lab teams in your class. **For more help, refer to the Science Skill Handbook.** 



# The Impossible Dream

A machine that keeps on going? It has been tried for hundreds of years.

any people have tried throughout history-and failed-to build perpetualmotion machines. In theory, a perpetual-motion machine would run forever and do work without a continual source of energy. You can think of it as a car that you could fill up once with gas, and the car would run forever. Sound impossible? It is!

#### **Science Puts Its Foot Down**

For hundreds of years, people have tried to create perpetual-motion machines. But these machines won't work because they violate two of nature's laws. The first law is the law of conservation of energy, which states that energy cannot be created or destroyed. It can change form—say,

from mechanical energy to electrical energy—but you always end up with the same amount of energy that you started with.

How does that apply to perpetual-motion machines? When a machine does work on an object, the machine transfers energy to the object.



Unless that machine gets more energy from somewhere else, it can't keep doing work. If it did, it would be creating energy.

The second law states that heat by itself always flows from a warm object to a cold object. Heat will only flow from a cold object to a warm object if work is done. In the process, some heat always escapes.

To make up for these energy losses, energy constantly needs to be transferred to the machine. Otherwise, it stops. No perpetual motion. No free electricity. No devices that generate more energy than they use. No engine motors that run forever without refueling. Some laws just can't be broken.

Visitors look at the Keely Motor, the most famous perpetual-motion machine fraud of the late 1800s.

Analyze Using your school or public-library resources, locate a picture or diagram of a perpetual-motion machine. Figure out why it won't run forever. Explain to the class what the problem is.

For more information, visit gpescience.com

# **Reviewing Main Ideas**

# Section 1 The Nature of Energy

- **1.** Energy is the ability to cause change.
- **2.** Energy can have different forms, including kinetic, potential, and thermal energy.

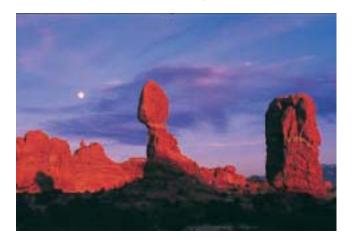


**3.** Moving objects have kinetic energy that depends on the object's mass and velocity, and can be calculated from this equation:

$$KE = \frac{1}{2} mv^2$$

**4.** Potential energy is stored energy. An object can have gravitational potential energy that depends on its mass and its height, and is given by this equation:

$$GPE = mgh$$



# Section 2 Conservation of Energy

- 1. Energy can change from one form to another. Devices you use every day transform one form of energy into other forms that are more useful.
- 2. Falling, swinging, and projectile motion all involve transformations between kinetic energy and gravitational potential energy.
- **3.** The total amount of kinetic energy and gravitational potential energy in a system is the mechanical energy of the system:

$$mechanical\ energy = KE + GPE$$

**4.** The law of conservation of energy states that energy never can be created or destroyed. The total amount of energy in the universe is constant.



- **5.** Friction converts mechanical energy into thermal energy, causing the mechanical energy of a system to decrease.
- **6.** Mass is converted into energy in nuclear fission and fusion reactions. Fusion and fission occur in the nuclei of certain atoms, and release tremendous amounts of energy.

**FOLDABLES** Use the Foldable you made at the beginning of this chapter to review what you learned about energy.

# **Using Vocabulary**

chemical potential energy p. 131 elastic potential energy p. 131 energy p. 128 gravitational potential energy p. 132 joule p. 130 kinetic energy p. 130 law of conservation of energy p. 139 mechanical energy p. 136 potential energy p. 131

Complete each statement using a word(s) from the vocabulary list above.

- **1.** If friction can be ignored, the \_\_\_\_\_ of a system doesn't change.
- **2.** The energy stored in a compressed spring is
- **3.** The \_\_\_\_\_ is the SI unit for energy.
- **4.** When a book is moved from a higher shelf to a lower shelf, its \_\_\_\_\_ changes.
- **5.** The muscles of a runner transform chemical potential energy into \_\_\_\_\_.
- **6.** According to the \_\_\_\_\_\_, the amount of energy in the universe doesn't change.

# **Checking Concepts**

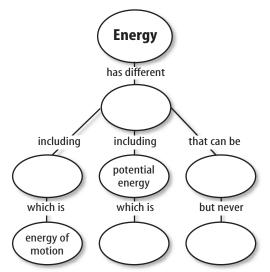
Choose the word or phrase that best answers the question.

- **7.** What occurs when energy is transferred from one object to another?
  - A) an explosion
  - B) a chemical reaction
  - **C)** nuclear fusion
  - **D)** a change
- **8.** For which of the following is kinetic energy converted into potential energy?
  - A) a boulder rolls down a hill
  - B) a ball is thrown upward
  - **C)** a swing comes to a stop
  - **D)** a bowling ball rolls horizontally

- **9.** The gravitational potential energy of an object changes when which of the following changes?
  - A) the object's speed
  - B) the object's mass
  - **c)** the object's temperature
  - **D)** the object's length
- **10.** Friction causes mechanical energy to be transformed into which of these forms?
  - **A)** thermal
- **c)** kinetic
- **B)** nuclear
- **D)** potential
- **11.** The kinetic energy of an object changes when which of the following changes?
  - A) the object's chemical potential energy
  - **B)** the object's volume
  - **c)** the object's direction of motion
  - **D)** the object's speed
- **12.** When an energy transformation occurs, which of the following is true?
  - **A)** Mechanical energy doesn't change.
  - **B)** Mechanical energy is lost.
  - **c)** The total energy doesn't change.
  - **D)** Mass is converted into energy.

# **Interpreting Graphics**

**13.** Copy and complete the following concept map on energy.

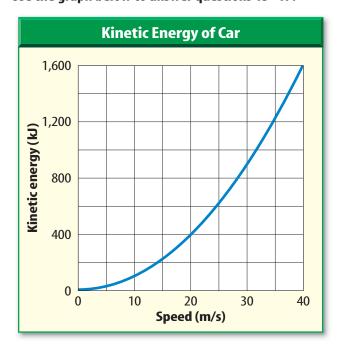


Use the table below to answer question 14.

Toy Cars Rolling Down Ramps					
Ramp Height (m)	Speed at Bottom (m/s)	GPE (J)	KE (J)		
0.50	3.13	Do	not		
0.75	3.83		te in		
1.00	4.43	this	book.		

14. Make and Use Tables Three toy cars, each with a mass of 0.05 kg, roll down ramps with different heights. The height of each ramp and the speed of each car at the bottom of each ramp is given in the table. Copy and complete the table by calculating the GPE of each car at the top of the ramp and the KE for each car at the bottom of the ramp to two decimal places. How do the values of GPE and KE you calculate compare?

Use the graph below to answer questions 15–17.



**15.** When the car's speed doubles from 20 m/s to 40 m/s, by how many times does the car's kinetic energy increase?

- **16.** Using the graph, estimate the car's kinetic energy at a speed of 50 m/s.
- **17.** If the car's kinetic energy at a speed of 20 m/s is 400 kJ, what is the car's kinetic energy at a speed of 10 m/s?

# **Thinking Critically**

- **18. Describe** the energy changes that occur in a swing. Explain how energy is conserved as the swing slows down and stops.
- **19. Explain** why the law of conservation of energy must also include changes in mass.
- **20. Infer** why the tires of a car get hot when the car is driven.
- **21. Diagram** On a cold day you rub your hands together to make them warm. Diagram the energy transformations that occur, starting with the chemical potential energy stored in your muscles.

# **Applying Math**

- **22. Calculate Kinetic Energy** What is the kinetic energy of a 0.06-kg tennis ball traveling at a speed of 150 m/s?
- **23. Calculate Potential Energy** A boulder with a mass of 2,500 kg rests on a ledge 200 m above the ground. What is the boulder's potential energy?
- **24. Calculate Mechanical Energy** What is the mechanical energy of a 500-kg roller-coaster car moving with a speed of 3 m/s at the top of hill that is 30 m high?
- **25. Calculate Speed** A boulder with a mass of 2,500 kg on a ledge 200 m above the ground falls. If the boulder's mechanical energy is conserved, what is the speed of the boulder just before it hits the ground?

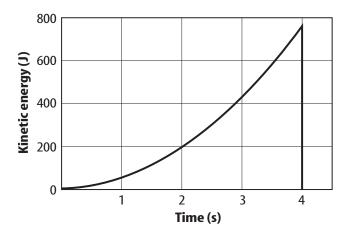
Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

### **Multiple Choice**

- **1.** What is the potential energy of a 5.0-kg object located 2.0 m above the ground?
  - **A.** 2.5 J
  - **B.** 10 J
  - **c.** 98 J
  - **D.** 196 J

Use the figure below to answer questions 2-4.

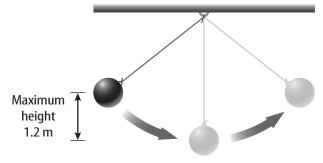
#### **Kinetic Energy of Falling Rock**



- **2.** According to the graph, which of the following is the best estimate for the kinetic energy of the rock after it has fallen for 1 s?
  - **A.** 100 J
  - **B.** 50 J
  - **c.** 200 J
  - **D.** 0 J

- 3. According to the graph, which of the following is the best estimate for the potential energy of the rock before it fell?
  - **A.** 400 J
  - **B.** 750 J
  - **c.** 200 J
  - **D.** 0 J
- **4.** If the rock has a mass of 1 kg, which of the following is the speed of the rock after it has fallen for 2 s?
  - **A.** 10 m/s
  - **B.** 100 m/s
  - **c.** 20 m/s
  - **D.** 200 m/s

Use the figure below to answer questions 5 and 6.



- **5.** At its highest point, the pendulum is 1.2 m above the ground and has a gravitational potential energy of 62 J. If the gravitational potential energy is 10 J at its lowest point, what is the pendulum's kinetic energy at this point?
  - **A.** 0 J
  - **B.** 31 J
  - **c.** 62 J
  - **D.** 52 J

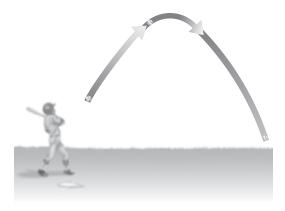
- **6.** What is the mass of the pendulum bob?
  - **A.** 2.7 kg
  - **B.** 5.3 kg
  - **c.** 6.3 kg
  - **D.** 52 kg

# **Gridded Response**

7. What is the difference, in J, in the gravitational potential energy of a 7.75-kg book that is 1.50 m above the ground and a 9.53-kg book that is 1.75 m above the ground?

#### **Short Response**

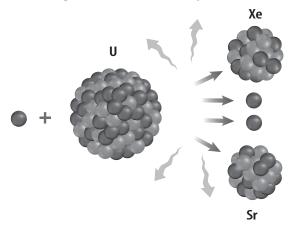
Use the figure below to answer question 8.



- **8.** How does the mechanical energy of the ball change from the moment just after the batter hits it to the moment just before it touches the ground?
- **9.** Explain why the law of conservation of energy also includes mass when applied to nuclear reactions.

#### **Extended Response**

Use the figure below to answer question 10.



- **10.** The figure shows a nuclear reaction.
  - **Part A** Describe the process and explain how it obeys the law of conservation of energy.
  - **Part B** Describe how the total mass of the particles before the reaction occurs compares to the total mass of the particles produced by the reaction.
- **11.** Describe a process in which energy travels through the environment and changes from one form to another.

#### Test-Taking Tip

**Show All Your Work** For extended response questions, show all your work and any calculations on your answer sheet.

**Question 10** On your answer sheet, list the energy changes that occur during each step.

# chapter



#### BIG (Idea

Machines make doing work easier by changing the force needed to do the work.

#### 6.1 Work

MAIN (Idea Work is done when a force causes something to move.

### **6.2 Using Machines**

MAIN (Idea A machine can change the force needed to do a job, but it can't reduce the amount of work needed.

### **6.3 Simple Machines**

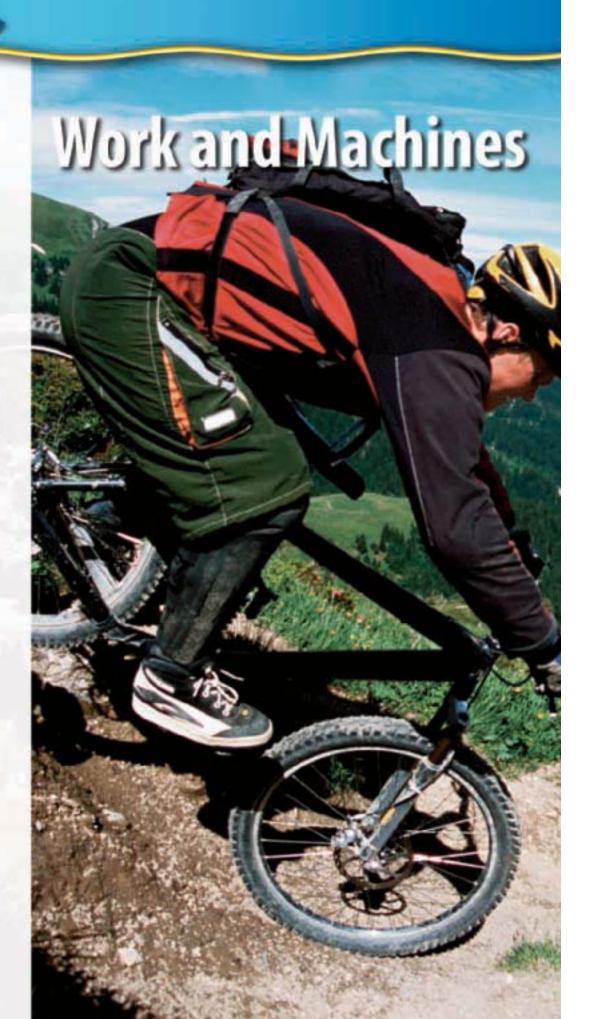
MAIN (Idea Compound machines are made from six types of simple machines.

#### Work with Me

Have you ever thought of a mountain bike as a machine? A mountain bike is actually a combination of simple machines. Like all machines, a bicycle makes doing a job easier. A mountain bike, for example, helps you travel faster than you could by running or walking.

#### Science Journal

Diagram a bicycle and identify the parts you think are simple machines.



# **Start-Up Activities**



# **Doing Work with a Simple Machine**

Did you know you can lift several times your own weight with the help of a pulley? Before the hydraulic lift was invented, a car mechanic used pulleys to raise a car off the ground. In this lab you'll see how a pulley can increase a force.



- **1.** Complete the safety form.
- Tie a rope several meters in length to the center of a broom handle. Have one student hold both ends of the handle.
- 3. Have another student hold the ends of a second broom handle and face the first student as shown in the photo.
- 4. Have a third student loop the free end of the rope around the second handle, making six or seven loops.
- 5. The third student should stand to the side of one of the handles and pull on the free end of the rope. The two students holding the broom handles should prevent the handles from coming together.
- **6. Think Critically** Describe how the applied force was changed. What would happen if the number of rope loops were increased?



Work and Machines Make the following Foldable to help you understand how machines make doing work easier.

Fold a sheet of paper vertically in half from top to bottom.



**STEP 2 Fold** in half from side to side with the fold at the top.



STEP 3 Unfold the paper once. Cut only the fold of the top flap to make two tabs.



Turn the paper vertically and label the front tabs as shown.



**List** Before you read the chapter, list five examples of work you do without machines, and five examples of work you do with machines. Next to each example, rate the effort needed to do the work on a scale of 1 (little effort) to 3 (much effort).



Preview this chapter's content and activities at gpescience.com

# **Reading Guide**

# **What** You'll Learn

- Explain the meaning of work.
- Describe how work and energy are related.
- Calculate work.
- Calculate power.

# Why It's Important

Doing work is another way of transferring energy from one place to another.

### Review Vocabulary

energy: the ability to cause change

#### **New Vocabulary**

- work
- power

**Figure 1** When you lift a stack of books, your arms apply a force upward and the books move upward. Because the force and distance are in the same direction, your arms have done work on the books.



# What is work?

Have you done any work today? To many people, the word *work* means something they do to earn money. In that sense, work can be anything from filling fast-food orders or loading trucks to teaching or doing word processing on a computer. The word *work* also means exerting a force with your muscles. A person might say he or she does work while pushing as hard as they can against a wall that doesn't move. However, in science the word *work* is used in a different way.

Work Makes Something Move Press your hand against the surface of your desk as hard as you can. Have you done any work? The answer is no, no matter how tired your effort makes you feel. Remember that a force is a push or a pull. For work to be done, a force must make something move. Work is the energy transferred when a force makes an object move. If you push against the desk and it doesn't move, then you haven't done any work on the desk.

**Doing Work** There are two conditions that have to be satisfied for a force to do work on an object. One is that the applied force must make the object move, and the other is that the movement must be in the same direction as the applied force.

For example, if you pick up a pile of books from the floor, as in **Figure 1**, you do work on the books. The books move upward, in the direction of the force you are applying. If you hold the books in your arms without moving the books, you are not doing work on the books. You're still applying an upward force to keep the books from falling, but no movement is taking place.

Force and Direction of Motion When you carry books while walking, like the student in Figure 2, you might think that your arms are doing work. After all, you are exerting a force on the books with your arms, and the books are moving. Your arms might even feel tired. However, in this case the force exerted by your arms does no work on the books. The force exerted by your arms on the books is upward, but the books are moving horizontally. The force you exert upward is at right angles to the direction the books are moving. As a result, your arms exert no force in the direction the books are moving.



How are an applied force and an object's motion related when work is done?

# **Work and Energy**

How are work and energy related? When work is done, a transfer of energy always occurs. This is easier to understand when you think about carrying a heavy box up a flight of stairs. Remember that when the height of an object above Earth's surface increases, the gravitational potential energy of the object increases. As you move up the stairs, you increase the height of the box above Earth's surface. This causes the gravitational potential energy of the box to increase.

You may recall that energy is the ability to cause change. If something has energy, it can transfer energy to another object by doing work on that object. When you do work on an object, you increase its energy. The student carrying the box in **Figure 3** transfers chemical energy in his muscles to the box. Energy is always transferred from the object that is doing the work to the object on which the work is done.



Distance

**Figure 2** If you hold a stack of books and walk forward, your arms are exerting a force upward. However, the distance the books move is horizontal. Therefore, your arms are not doing work on the books.



**Figure 3** By carrying a box up the stairs, you are doing work. You transfer energy to the box. **Explain** how the energy of the box changes as the student climbs the stairs.

**Calculating Work** The amount of work done depends on the amount of force exerted and the distance over which the force is applied. When a force is exerted and an object moves in the direction of the force, the amount of work done can be calculated as follows.

#### **Work Equation**

work (in joules) = applied force (in newtons)  $\times$  distance (in meters) W = Fd

In this equation, force is measured in newtons and distance is measured in meters. Work, like energy, is measured in joules. One joule is about the amount of work required to lift a baseball a vertical distance of 0.7 m.

# **Applying Math**

### **Solve a Simple Equation**

**WORK** You push a refrigerator with a force of 100 N. If you move the refrigerator a distance of 5 m, how much work do you do?

#### **IDENTIFY** known values and the unknown value

#### Identify the known values:

you push a refrigerator with a force of 100 N means F = 100 Nyou move the refrigerator a distance of 5 m means d = 5 m

#### Identify the unknown value:

how much work you do M=? J

#### SOLVE the problem

Substitute the known values F = 100 N and d = 5 m into the work equation.

$$W = Fd = (100 \text{ N}) (5 \text{ m}) = 500 \text{ Nm} = 500 \text{ J}$$

#### **CHECK** your answer

Does your answer seem reasonable? Check your answer by dividing the work you calculated by the force given in the problem. The result should be the distance given in the problem.

#### **Practice Problems**

- **1.** A force of 75 N is exerted on a 45-kg couch, and the couch is moved 5 m. How much work is done in moving the couch?
- **2.** A lawn mower is pushed with a force of 80 N. If 12,000 J of work is done in mowing a lawn, what is the total distance the lawn mower was pushed?
- **3.** The brakes on a car do 240,000 J of work in stopping the car. If the car travels a distance of 50 m while the brakes are being applied, what is the force the brakes exert on the car?

For more practice problems go to page 879, and visit Math Practice at gpescience.com.



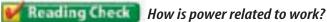
Figure 4 A pitcher exerts a force on the ball to throw it to the catcher. After the ball leaves her hand, the pitcher no longer is exerting any force on the ball. She does work on the ball only while it is in her hand.

When is work done? Suppose you give a book a push and it slides along a table for a distance of 1 m before it comes to a stop. The distance you use to calculate the work you did is how far the object moved while the force was being applied. Even though the book moved 1 m, you did work on the book only while your hand was in contact with it. The distance in the formula for work is the distance the book moved while your hand was pushing on the book. As **Figure 4** shows, work is done on an object only when a force is being applied to the object.

# **Power**

Suppose you and another student are pushing boxes of books up a ramp to load them into a truck. To make the job fun, you make a game of it, racing to see who can push a box up the ramp faster. The boxes weigh the same, but your friend is able to push a box a little faster than you can. She moves a box up the ramp in 30 s. It takes you 45 s. You both do the same amount of work on the books because the boxes weigh the same and are moved the same distance. The only difference is the time it takes to do the work.

In this game, your friend has more power than you do. **Power** is the amount of work done in one second. It is a rate, the rate at which work is done.





#### **Calculating Your** Work and Power

#### **Procedure**

- 1. Complete the safety form.
- 2. Find a set of **stairs** that you can safely walk and run up. Measure the vertical height of the stairs in meters.
- 3. Record how many seconds it takes you to walk and then run up the stairs.
- 4. Calculate the work you did in both walking and running up the stairs. The force is your weight in newtons (your weight in pounds times 4.5). The distance is the vertical height of the stairs.
- **5.** Use the formula P = W/tto calculate the power you needed to both walk and to run up the stairs.

#### **Analysis**

- 1. Is the work you did walking and running up the steps the same?
- 2. Which required more power, walking or running up the steps? Why?

**Calculating Power** Power is the rate at which work is done. To calculate power, divide the work done by the time that is required to do the work.

#### **Power Equation**

$$\frac{\text{power (in watts)}}{\text{time (in seconds)}}$$

$$P = \frac{W}{t}$$

The SI unit for power is the watt (W). One watt equals one joule of work done in one second. Because the watt is a small unit, power often is expressed in kilowatts. One kilowatt (kW) equals 1,000 W.

## **Applying Math**

#### **Solve a Simple Equation**

**POWER** You do 900 J of work in pushing a sofa. If it took 5 s to move the sofa, what was your power?

**IDENTIFY** known values and the unknown value

Identify the known values:

You do 900 J of work 
$$M = 900 \text{ J}$$

it took 5 s to move the sofa 
$$t = 5$$
 s

Identify the unknown value:

what was your power? 
$$\longrightarrow$$
  $P = ? W$ 

**SOLVE** the problem

Substitute the known values W = 900 J and t = 5 s into the power equation.

$$P = \frac{W}{t} = \frac{900 \text{ J}}{5 \text{ s}} = 180 \text{ J/s} = 180 \text{ W}$$

#### **CHECK** your answer

Does your answer seem reasonable? Check your answer by multiplying the power you calculated by the time given in the problem. The result should be the work given in the problem.

#### **Practice Problems**

- 1. To lift a baby from a crib, 50 J of work is done. How much power is needed if the baby is lifted in 0.5 s?
- 2. If a runner's power is 130 W, how much work is done by the runner in 10 minutes?
- 3. The power produced by an electric motor is 500 W. How long will it take the motor to do 10,000 J of work?

For more practice problems go to page 879, and visit Math Practice at gpescience.com.

The symbol for work, W, is usually italicized. However, the abbreviation for watt, W, is not italicized.

**Power and Energy** Doing work is a way of transferring energy from one object to another. Just as power is the rate at which work is done, power is also the rate at which energy is transferred. When energy is transferred, the power involved can be calculated by dividing the energy transferred by the time needed for the transfer to occur.

#### **Power Equation for Energy Transfer**

For example, when the lightbulb in **Figure 5** is connected to an electric circuit, energy is transferred from the circuit to the lightbulb filament. The filament converts the electrical energy supplied to the lightbulb into heat and light. The power used by the lightbulb is the amount of electrical energy transferred to the lightbulb each second.



Figure 5 This 100-W lightbulb converts electrical energy into light and heat at a rate of 100 J/s.

## section

## review

#### **Summary**

#### **Work and Energy**

- Work is done on an object when a force is exerted on the object and it moves in the direction of the force.
- If a force, F, is exerted on an object while the object moves a distance, *d*, in the direction of the force, the work done is

$$W = Fd$$

 When work is done on an object, energy is transferred to the object.

#### Power

- Power is the rate at which work is done or energy is transferred.
- When work is done, power can be calculated from the equation

$$P = \frac{W}{t}$$

• When energy is transferred, power can be calculated from the equation

$$P = \frac{E}{t}$$

#### Self Check

- **1. Explain** how the scientific definition of *work* is different from the everyday meaning.
- 2. **Describe** a situation in which a force is applied but no work is done.
- 3. Explain how work and energy are related.
- 4. Think Critically In which of the following situations is work being done?
  - a. A person shovels snow off a sidewalk.
  - **b.** A worker lifts bricks, one at a time, from the ground to the back of a truck.
  - **c.** A roofer's assistant carries a bundle of shingles across a construction site.

#### **Applying Math**

- **5. Calculate Force** Find the force a person exerts in pulling a wagon 20 m if 1,500 J of work is done.
- **6. Calculate Work** A car's engine produces 100 kW of power. How much work does the engine do in 5 s?
- **7. Calculate Energy** A color TV uses 120 W of power. How much energy does the TV use in 1 hour?

# section 2

# **Using Machines**

## **Reading Guide**

#### What You'll Learn

- Explain how machines make doing work easier.
- Calculate the mechanical advantage of a machine.
- Calculate the efficiency of a machine.

## Why It's Important

Cars, stairs, and teeth are all examples of machines that make your life easier.

#### Review Vocabulary

force: a push or a pull

#### **New Vocabulary**

- machine
- input force
- output force
- mechanical advantage
- efficiency

## What is a machine?

A **machine** is a device that makes doing work easier. When you think of a machine, you may picture a device with an engine and many moving parts. However, machines can be simple. Some machines, such as knives, scissors, and doorknobs, are used every day to make doing work easier.

## **Making Work Easier**

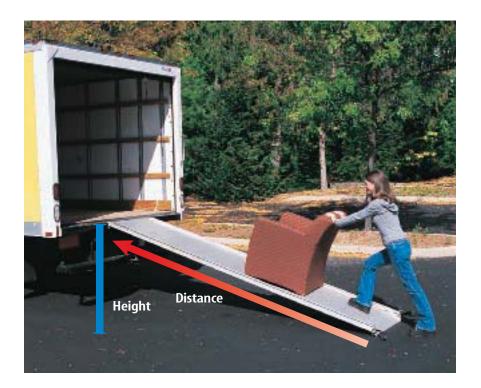
Machines can make work easier by increasing the force that can be applied to an object. A screwdriver increases the force you apply to a screw. A second way that machines can make work easier is by increasing the distance over which a force can be applied. A leaf rake is an example of this type of machine.

Machines also can make work easier by changing the direction of an applied force. A simple pulley changes a downward force to an upward force.

**Increasing Force** A car jack, such as the one in **Figure 6**, is an example of a machine that increases an applied force. The upward force exerted by the jack is greater than the downward force you exert on the handle. However, the distance you push the handle downward is greater than the distance the car is pushed upward. Because work is the product of force and distance, the work done by the jack is not greater than the work you do on the jack. The jack increases the applied force, but it doesn't increase the work done.

**Figure 6** A car jack is an example of a machine that increases an applied force.





**Figure 7** Whether the mover slides the chair up the ramp or lifts it directly into the truck, she will do the same amount of work. Doing the work over a longer distance allows her to use less force.

**Force and Distance** Why does the mover in **Figure 7** push the heavy furniture up the ramp instead of lifting it into the truck? It is easier because less force is needed to push the furniture up the ramp than is needed to lift it.

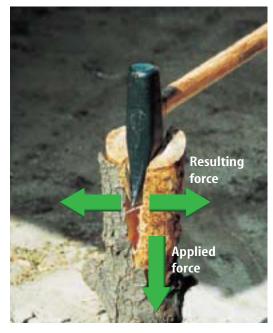
The work done in lifting an object depends on the change in height of the object. The same amount of work is done whether the mover pushes the furniture up the long ramp or lifts it straight up. If she uses a ramp to lift the furniture, she moves the furniture a longer distance than if she just raised it straight up. If the work stays the same and the distance is increased, then less force will be needed to do the work.

**Figure 8** An ax blade changes the direction of the force from vertical to horizontal.

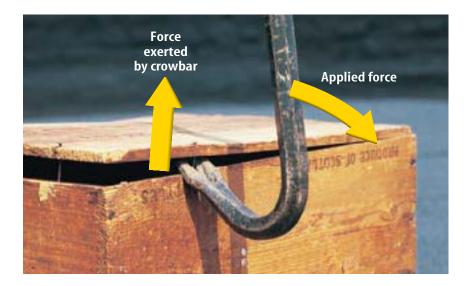


How does a ramp make lifting an object easier?

**Changing Direction** Some machines change the direction of the force you apply. When you use the car jack, you exert a force downward on the jack handle. The force exerted by the jack on the car is upward. The direction of the force you apply is changed from downward to upward. Some machines change the direction of the force that is applied to them in another way. The wedgeshaped blade of an ax is one example. When you use an ax to split wood, you exert a downward force as you swing the ax toward the wood. As **Figure 8** shows, the blade changes the downward force into a horizontal force that splits the wood apart.



**Figure 9** A crowbar increases the force you apply and changes its direction.





## **Machines Multiplying Force**

#### 

- 1. Complete the safety form.
- 2. Open a can of food using a manual can opener that has circular blades.

  WARNING: Do not touch can opener's cutting blades or the cut edges of the cans' lids.
- 3. Open another can of food, but this time grasp the handle as close as you can to the handle's pivot point.

#### **Analysis**

- Compare how difficult it was to open the first can with how difficult it was to open the second can.
- 2. Infer why a can opener makes it easier to open a metal can. How would you design a can opener to make opening cans even easier?

## **The Work Done by Machines**

To pry the lid off a wooden crate with a crowbar, you'd slip the end of the crowbar under the edge of the crate lid and push down on the handle. By moving the handle downward, you do work on the crowbar. As the crowbar moves, it does work on the lid, lifting it up. **Figure 9** shows how the crowbar increases the amount of force being applied and changes the direction of the force.

When you use a machine such as a crowbar, you are moving something that resists being moved. For example, if you use a crowbar to pry the lid off a crate, you are working against the friction between the nails in the lid and the crate. You also could use a crowbar to move a large rock. In this case, you would be working against gravity—the weight of the rock.

**Input and Output Forces** Two forces are involved when a machine is used to do work. You exert a force on the machine, such as a bottle opener, and the machine then exerts a force on the object you are trying to move, such as a bottle cap. The force that is applied to the machine is called the **input force**.  $F_{in}$  stands for the input force. The force applied by the machine is called the **output force**, symbolized by  $F_{out}$ . When you try to pull a nail out of wood with a hammer, as in **Figure 10**, you apply the input force on the handle. The output force is the force the claw applies to the nail.

Two kinds of work need to be considered when you use a machine: the work done by you on the machine and the work done by the machine. When you use a crowbar, you do work when you apply force to the crowbar handle and make it move. The work done by you on a machine is called the input work and is symbolized by  $W_{\rm in}$ . The work done by the machine is called the output work and is abbreviated  $W_{\rm out}$ .

**Conserving Energy** Remember that energy is always conserved. When you do work on a machine, you transfer energy to the machine. When the machine does work on an object, energy is transferred from the machine to the object. Because energy cannot be created or destroyed, the amount of energy the machine transfers to the object cannot be greater than the amount of energy you transfer to the machine. A machine cannot create energy, so  $W_{\text{out}}$  is never greater than  $W_{\text{in}}$ .

However, the machine does not transfer all of the energy it receives to the object. In fact, when a machine is used, some of the input energy changes to thermal energy due to friction. The energy that changes to thermal energy cannot be used to do work, so  $W_{\text{out}}$  is always smaller than  $W_{\text{in}}$ .

**Ideal Machines** Remember that work is calculated by multiplying force by distance. The input work is the product of the input force and the distance over which the input force is exerted. The output work is the product of the output force and the distance over which that force is exerted.

Suppose a perfect machine could be built in which there were no friction. None of the input work or output work would be converted to thermal energy. For such an ideal machine, the input work would equal the output work. For an ideal machine,

$$W_{\rm in} = W_{\rm out}$$

Suppose the ideal machine increases the force applied to it. This means that the output force,  $F_{\rm out}$ , is greater than the input force,  $F_{\rm in}$ . Recall that work is equal to force times distance. If  $F_{\rm out}$  is greater than  $F_{\rm in}$ , then  $W_{\rm in}$  and  $W_{\rm out}$  can be equal only if the input force is applied over a greater distance than the output force.

For example, suppose the hammer claw in **Figure 10** moves a distance of 1 cm to remove a nail. If an output force of 1,500 N is exerted by the claw of the hammer, and you move the handle of the hammer 5 cm, you can find the input force as follows.

$$W_{\text{in}} = W_{\text{out}}$$

$$F_{\text{in}} d_{\text{in}} = F_{\text{out}} d_{\text{out}}$$

$$F_{\text{in}} (0.05 \text{ m}) = (1,500 \text{ N}) (0.01 \text{ m})$$

$$F_{\text{in}} (0.05 \text{ m}) = 15 \text{ N} \cdot \text{m}$$

$$F_{\text{in}} = 300 \text{ N}$$

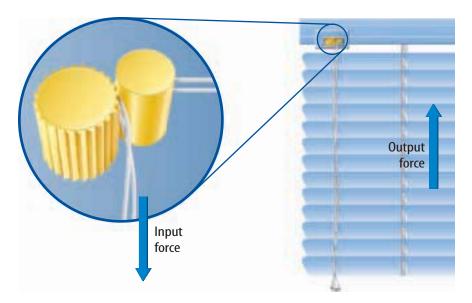
Because the distance you move the hammer is longer than the distance the hammer moves the nail, the input force is less than the output force.



**Figure 10** When prying a nail out of a piece of wood with a claw hammer, you exert the input force on the handle of the hammer, and the claw exerts the output force. **Describe** how the hammer changes the input force.



burst a balloon.



**Figure 11** Window blinds use a machine that changes the direction of an input force. A downward pull on the cord is changed to an upward force on the blinds. The input and output forces are equal, so the *MA* is 1.



# Graphite is a solid that sometimes is used as a lubricant to increase the efficiency of machines. Find out what element graphite is made of and why graphite is a good

lubricant.

# **Mechanical Advantage**

Machines such as the car jack, the ramp, the crow bar, and the claw hammer make work easier by making the output force greater than the input force. The ratio of the output force to the input force is the **mechanical advantage** of a machine. The mechanical advantage (*MA*) of a machine can be calculated with the following equation.

#### **Mechanical Advantage Equation**

**Figure 11** shows that the mechanical advantage equals one when only the direction of the input force changes.

**Ideal Mechanical Advantage** The mechanical advantage of a machine without friction is called the ideal mechanical advantage, or *IMA*. The *IMA* can be calculated by dividing the input distance by the output distance. For a real machine, the *IMA* would be the mechanical advantage of the machine if there were no friction.

## **Efficiency**

For real machines, some of the energy put into a machine is always converted to thermal energy by frictional forces. For this reason, the output work of a machine is always less than the work put into the machine.

**Efficiency** is a measure of how much of the work put into a machine is changed into useful output work by the machine. A machine with high efficiency produces less thermal energy from friction, so more of the input work is changed to useful output work.



Why is the output work always less than the input work for a real machine?

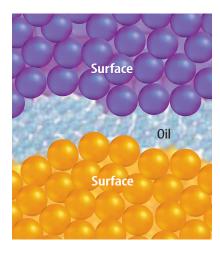
**Calculating Efficiency** To calculate the efficiency of a machine, the output work is divided by the input work. Efficiency is usually expressed as a percentage by this equation:

#### **Efficiency Equation**

efficiency (%) = 
$$\frac{\text{output work (in joules)}}{\text{input work (in joules)}} \times 100\%$$
$$efficiency = \frac{W_{\text{out}}}{W_{\text{in}}} \times 100\%$$

In an ideal machine, there is no friction and the output work equals the input work. So the efficiency of an ideal machine is 100 percent. In a real machine, friction causes the output work to always be less than the input work. So the efficiency of a real machine is always less than 100 percent.

**Increasing Efficiency** Machines can be made more efficient by reducing friction. This usually is done by adding a lubricant, such as oil or grease, to surfaces that rub together, as shown in **Figure 12.** A lubricant fills in the gaps between the surfaces, enabling the surfaces to slide past each other more easily.



**Figure 12** Oil reduces the friction between two surfaces. Oil fills the space between the surfaces so high spots don't rub against each other.

## section (2) review

#### **Summary**

#### **Work and Machines**

- Machines make doing work easier by changing the applied force, changing the distance over which the force is applied, or changing the direction of the applied force.
- Because energy cannot be created or destroyed, the output work cannot be greater than the input work.
- In a real machine, some of the input work is converted into heat by friction.

#### **Mechanical Advantage and Efficiency**

 The mechanical advantage of a machine is the output force divided by the input force:

$$MA = \frac{F_{\text{out}}}{F_{\text{in}}}$$

 The efficiency of a machine is the output work divided by the input work times 100%:

efficiency = 
$$\frac{W_{\text{out}}}{W_{\text{in}}} \times 100\%$$

#### **Self Check**

- 1. **Describe** the circumstances for which the output work would equal the input work in a machine.
- **2. Infer** how lubricating a machine affects the output force exerted by the machine.
- **3. Explain** why, in a real machine, the output work is always less than the input work.
- **4. Think Critically** The mechanical advantage of a machine is less than one. Compare the distances over which the input and output forces are applied.

#### **Applying Math**

- **5. Calculate** the mechanical advantage of a hammer if the input force is 125 N and the output force is 2,000 N.
- **6. Calculate Efficiency** Find the efficiency of a machine that does 800 J of work if the input work is 2,400 J.
- Calculate Force Find the force needed to lift a 2,000-N weight using a machine with a mechanical advantage of 15.

# **Simple Machines**

## **Reading Guide**

#### What You'll Learn

- Describe the six types of simple machines.
- **Explain** how the different types of simple machines make doing work easier.
- Calculate the ideal mechanical advantage of the different types of simple machines.

## Why It's Important

All complex machines, such as cars, are made of simple machines. Even your body contains simple machines.

#### Review Vocabulary

compound: composed of separate elements or parts

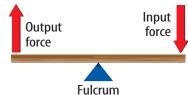
#### New Vocabulary

- simple machine
- lever
- pullev
- wheel and axle
- inclined plane
- screw
- wedge
- compound machine

**Figure 13** There are three classes of levers.

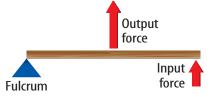
#### First-Class Lever

The fulcrum is between the input force and the output force.



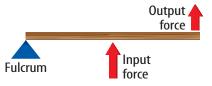
#### **Second-Class Lever**

The output force is between the fulcrum and the input force.



#### **Third-Class Lever**

The input force is between the fulcrum and the output force.



## **Types of Simple Machines**

If you cut your food with a knife, use a screwdriver, or even chew your food, you are using a simple machine. A simple machine is a machine that does work with only one movement of the machine. There are six types of simple machines: lever, pulley, wheel and axle, inclined plane, screw, and wedge. The pulley and the wheel and axle are modified levers, and the screw and the wedge are modified inclined planes.

## Levers

You've used a lever if you've used a wheelbarrow, a lawn rake, or swung a baseball bat. A **lever** is a bar that is free to pivot or turn around a fixed point. The fixed point the lever pivots on is called the fulcrum. The input arm of the lever is the distance from the fulcrum to the point where the input force is applied. The output arm is the distance from the fulcrum to the point where the output force is exerted by the lever.

The output force produced by a lever depends on the lengths of the input arm and the output arm. If the output arm is longer than the input arm, the law of conservation of energy requires that the output force be less than the input force. If the output arm is shorter than the input arm, then the output force is greater than the input force.

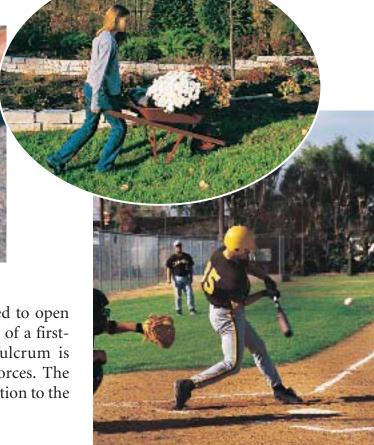
There are three classes of levers, as shown in **Figure 13.** The differences among the three classes of levers depend on the locations of the fulcrum, the input force, and the output force.

**Figure 14** Levers are classified by the locations of the input force, the output force, and the fulcrum.

B A wheelbarrow is a second-class lever. The fulcrum is the wheel.

A The screwdriver is being used as a first-class lever. The fulcrum is the paint can rim.





**First-Class Lever** The screwdriver used to open the paint can in Figure 14A is an example of a firstclass lever. For a first-class lever, the fulcrum is located between the input and output forces. The output force is always in the opposite direction to the input force in a first-class lever.

**Second-Class Lever** For a second-class lever, the output force is located between the input force and the fulcrum. Look at the wheelbarrow in Figure 14B. The girl applies an upward input force on the handles, and the wheel is the fulcrum. The output force is exerted between the input force and the fulcrum. For a second-class lever, the output force is always greater than the input force.

**Third-Class Lever** Many pieces of sports equipment, such as a baseball bat, are third-class levers. For a third-class lever, the input force is applied between the output force and the fulcrum. The right-handed batter in Figure 14C applies the input force with the right hand, and the left hand is the fulcrum. The output force is exerted by the bat above the right hand. The output force is always less than the input force in a third-class lever. Instead, the distance over which the output force is applied is increased.

Every lever can be placed in one of these classes. Each class can be found in your body, as shown in **Figure 15** on the next page.

A baseball bat is a third-class lever. The fulcrum here is the batter's left hand.



Archimedes and the Lever The Greek mathematician Archimedes (287-212 B.C.) described how a lever could be used to increase force. He also supposedly said "Give me a place to stand and I will move the Earth." Research one of Archimedes' inventions and write a paragraph describing it.

## NATIONAL GEOGRAPHIC VISUALIZING LEVERS IN THE HUMAN BODY

#### Figure 15

Il three types of levers—first-class, second-class, and third-class—are found in the human body. The forces exerted by muscles in your body can be increased by first-class and second-class levers, while third-class levers increase the range of movement of a body part. Examples of how the body uses levers to help it move are shown here.

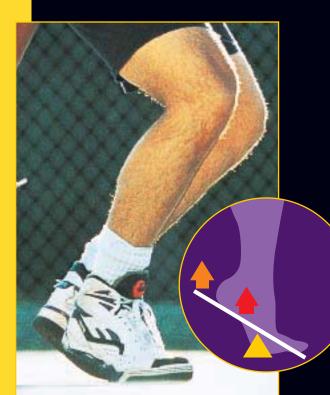


**▼** Input force

Output force



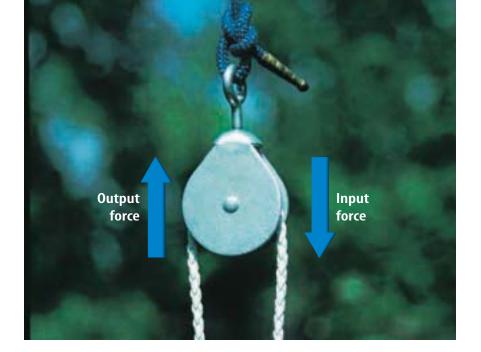
FIRST-CLASS LEVER The fulcrum lies between the input force and the output force. Your head acts like a first-class lever. Your neck muscles provide the input force to support the weight of your head.



SECOND-CLASS LEVER The output force is between the fulcrum and the input force. Your foot becomes a second-class lever when you stand on your toes.

THIRD-CLASS LEVER The input force is between the fulcrum and the output force. A third-class lever increases the range of motion of the output force. When you do a curl with a dumbbell, your forearm is a third-class lever.



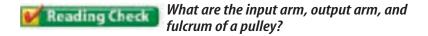


**Figure 16** A fixed pulley is another form of the lever. **Infer** the lengths of the input arm and output arm in a pulley.

**Ideal Mechanical Advantage of a Lever** The ideal mechanical advantage, or *IMA*, for a lever can be calculated by dividing the length of the input arm by the length of the output arm:

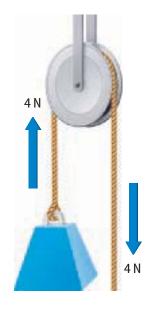
## **Pulleys**

A **pulley** is a grooved wheel with a rope, chain, or cable running along the groove. A fixed pulley, as shown in **Figure 16**, is a modified first-class lever. The axle of the pulley acts as the fulcrum. The two sides of the pulley are the input arm and output arm. A pulley can change the direction of the input force or increase the output force, depending on whether the pulley is fixed or movable. A system of pulleys can change the direction of the input force and make the output force larger.



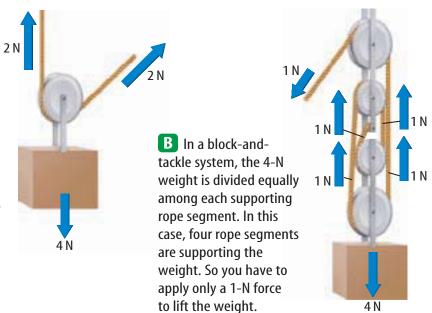
**Fixed Pulleys** The cable attached to an elevator passes over a fixed pulley at the top of the elevator shaft. A fixed pulley, such as the one in **Figure 17**, is attached to something that doesn't move, such as a ceiling or wall. Because a fixed pulley changes only the direction of force, the IMA is 1.

**Figure 17** A fixed pulley changes only the direction of a force. You need to apply an input force of 4 N to lift the 4-N weight.



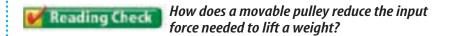
**Figure 18** A movable pulley and a pulley system called a block and tackle reduce the force needed to lift a weight.

A With a movable pulley, the attached side of the rope supports half of the 4-N weight. You have to apply a 2-N force to lift the weight.



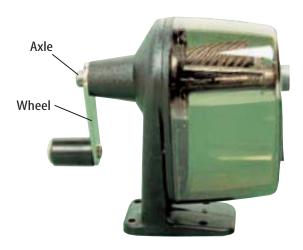
**Movable Pulleys** A pulley in which one end of the rope is fixed and the wheel is free to move is called a movable pulley. Unlike a fixed pulley, a movable pulley does multiply force. Suppose a 4-N weight is hung from the movable pulley in **Figure 18A.** The ceiling acts like someone helping you to lift the weight. The rope attached to the ceiling will support half of the weight—2 N. You need to exert only the other half of the weight—2 N—to support and lift the weight. The output force exerted on the weight is 4 N, and the applied input force is 2 N. Therefore the *IMA* of the movable pulley is 2.

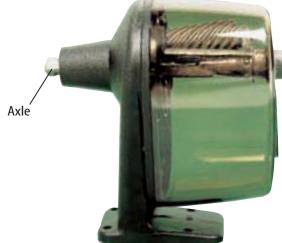
For a fixed pulley, the distance you pull the rope downward equals the distance the weight moves upward. For a movable pulley, the distance you pull the rope upward is twice the distance the weight moves upward.



The Block and Tackle A system of pulleys consisting of fixed and movable pulleys is called a block and tackle. **Figure 18B** shows a block and tackle made up of two fixed pulleys and two movable pulleys. If a 4-N weight is suspended from the movable pulley, each rope segment supports one-fourth of the weight, reducing the input force to 1 N. The *IMA* of a pulley system is equal to the number of rope segments that support the weight. The block and tackle shown in Figure 18B has an IMA of 4. The IMA of a block and tackle can be increased by increasing the number of pulleys in the pulley system.

**Figure 19** The handle on a pencil sharpener is part of a wheel and axle. You apply a force to the handle. This force is made larger by the wheel and axle, making it easy to turn the sharpening mechanism.





#### Wheel and Axle

Could you use the pencil sharpener in **Figure 19** if the handle weren't attached? The handle on the pencil sharpener is part of a wheel and axle. A wheel and axle is a simple machine consisting of a shaft or axle attached to the center of a larger wheel, so that the wheel and axle rotate together. Doorknobs, screwdrivers, and faucet handles are examples of wheel and axles. Usually, the input force is applied to the wheel, and the output force is exerted by the axle.

Mechanical Advantage of a Wheel and Axle Recall that the mechanical advantage of a lever is the length of the input arm divided by the length of the output arm. A wheel and axle is another modified lever. The center of the axle is the fulcrum. The input force is applied at the rim of the wheel. So the length of the input arm is the radius of the wheel. The output force is exerted at the rim of the axle. So the length of the output arm is the radius of the axle. The IMA of a wheel and axle is:

ideal mechanical advantage = 
$$\frac{\text{radius of wheel (m)}}{\text{radius of axle (m)}}$$

$$IMA = \frac{r_{\text{W}}}{r_{\text{a}}}$$

According to this equation, the IMA of a wheel and axle can be increased by increasing the radius of the wheel.



**Figure 20** If an input force is applied to the larger gear and it rotates clockwise, the smaller gear rotates counterclockwise. The output force exerted by the smaller gear is less than the input force applied to the larger gear.

**Gears** A gear is a wheel and axle with the wheel having teeth around its rim. When the teeth of two gears interlock, the turning of one gear causes the other gear to turn.

When two gears of different sizes are interlocked, they rotate at different rates. Each rotation of the larger gear causes the smaller gear to make more than one rotation. If the input force is applied to the larger gear, the output force exerted by the smaller gear is less than the input force.

Gears also may change the direction of the force, as shown in **Figure 20.** When

the larger gear in is rotated clockwise, the smaller gear rotates counterclockwise.

#### **Inclined Planes**

Why do the roads and paths on mountains zigzag? Would it be easier to climb directly up a steep incline or walk a longer path gently sloped around the mountain? An inclined plane is a sloping surface, such as a ramp, that reduces the amount of force required to do work.

Mechanical Advantage of an Inclined Plane You do the same work by lifting a box straight up or pushing it up an inclined plane. By pushing the box up an inclined plane, however, the input force is exerted over a longer distance compared to lifting the box straight up. As a result, the input force is less than the force needed to lift the box straight upward. The IMA of an inclined plane can be calculated from the following equation:

#### **Topic: Nanobots**

Visit gpescience.com for Web links to information about how tiny robots called nanobots might be used as microsurgical instruments.

**Activity** Use the information you find to make a diagram of a nanobot that might be used to perform surgery.

#### **IMA of an Inclined Plane**

ideal mechanical advantage = 
$$\frac{\text{length of slope (m)}}{\text{height of slope (m)}}$$
$$IMA = \frac{l}{h}$$

The IMA of an inclined plane for a given height is increased by making the plane longer.

When you think of an inclined plane, you might think of moving an object up a ramp—you move and the inclined plane remains stationary. The screw and the wedge, however, are variations of the inclined plane in which the inclined plane moves and the object remains stationary.

Figure 21 A screw has an inclined plane that wraps around the post of the screw.

The thread gets thinner farther from the post. This helps the screw force its way into materials.





Many lids, such as those on peanut butter jars, also contain threads.

#### **The Screw**

A screw is an inclined plane wrapped in a spiral around a cylindrical post. If you look closely at the screw in Figure 21, you'll see that the threads form a tiny ramp that runs upward from its tip. You apply the input force by turning the screw. The output force is exerted along the threads of the screw. The IMA of a screw is related to the spacing of the threads. The IMA is larger when the threads are closer together. However, when the IMA is larger, more turns of the screw are needed to drive it into a material.

How do you remove the lid from a jar of peanut butter, such as the one in **Figure 21?** If you look closely, you will see threads similar to the ones on the screw in **Figure 21.** Where else can you find examples of a screw?

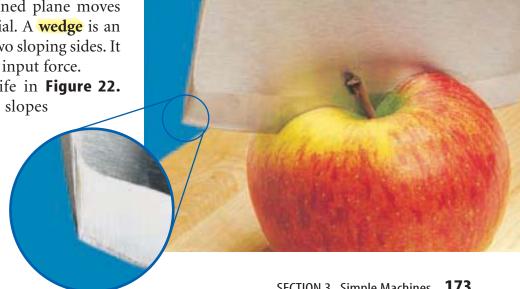
#### **Figure 22** A knife blade is a wedge. As you cut through the apple, the blade pushes the halves of the apple apart.

## The Wedge

Like the screw, the wedge is also a simple machine in which the inclined plane moves through an object or material. A wedge is an inclined plane with one or two sloping sides. It changes the direction of the input force.

Look closely at the knife in **Figure 22.** One edge is sharp, and it slopes

outward at both sides, forming an inclined plane. As it moves through the apple, the downward input force is changed to a horizontal force, forcing the apple apart.



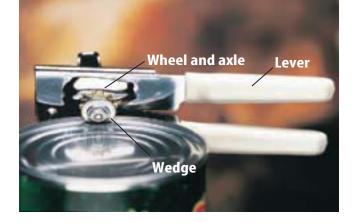


Figure 23 A compound machine, such as a can opener, is made up of simple machines.

## **Compound Machines**

Some of the machines you use every day are made up of several simple machines. Two or more simple machines that operate together form a compound machine.

Look at the can opener in **Figure 23.** To open the can, you first squeeze the handles together. The handles act as levers and increase the force applied on a wedge, which then pierces the can.

You then turn the handle, a wheel and axle, to open the can.

A car is also a compound machine. Burning fuel in the cylinders of the engine causes the pistons to move up and down. This up-and-down motion makes the crankshaft rotate. The force exerted by the rotating crankshaft is transmitted to the wheels through other parts of the car, such as the transmission and the differential. Both of these parts contain gears which can change the rate at which the wheels rotate, the force exerted by the wheels, and even reverse the direction of rotation.

#### section review

#### **Summary**

#### The Lever Family

- A lever is a bar that is free to pivot about a fixed point called the fulcrum.
- There are three classes of levers based on the relative locations of the input force, the output force, and the fulcrum.
- A pulley is a grooved wheel with a rope, chain, or cable placed in the groove and is a modified form of a lever.
- The *IMA* of a lever is the length of the input arm divided by the length of the output arm.
- A wheel and axle consists of a shaft or axle attached to the center of a larger wheel.

#### The Inclined Plane Family

- An inclined plane is a ramp or sloping surface that reduces the force needed to do work.
- The IMA of an inclined plane is the length of the plane divided by the height of the plane.
- A screw consists of an inclined plane wrapped around a shaft.
- A wedge is an inclined plane that moves and can have one or two sloping surfaces.

#### Self Check

- 1. Classify a screwdriver being used to turn a screw as one of the six types of simple machines. Explain how the IMA of a screwdriver could be increased.
- 2. **Determine** for which class of lever the output force is always greater than the input force. For which class is the output force always less than the input force?
- 3. Make a diagram of a bicycle and label the parts of a bicycle that are simple machines.
- **4. Think Critically** Use the law of conservation of energy to explain why, in a second-class lever, the distance over which the input force is applied is always greater than the distance over which the output force is applied.

#### **Applying Math**

- **5. Calculate** *IMA* What is the *IMA* of a car's steering wheel if the wheel has a diameter of 40 cm and the shaft it's attached to has a diameter of 4 cm?
- 6. Calculate Output Arm Length A lever has an IMA of 4. If the length of the input arm is 1.0 m, what is the length of the output arm?
- 7. Calculate IMA A 6.0-m ramp runs from a sidewalk to a porch that is 2.0 m above the sidewalk. What is the ideal mechanical advantage of this ramp?



## Levers

Have you ever tried to balance a friend on a seesaw? If your friend was lighter, you had to move toward the fulcrum. In this lab, you will use the same method to measure the mass of a coin.



How can a lever be used to measure mass?

#### Goals

- **Calculate** the ideal mechanical advantage of a lever.
- **Determine** the mass of a coin.

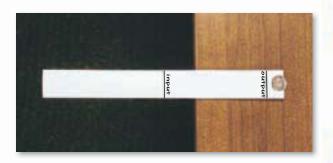
#### **Materials**

stiff cardboard, 3 cm by 30 cm coins (one quarter, one dime, one nickel) balance metric ruler

## Safety Precautions 🗫 🔙 📶

#### Procedure

- 1. Complete the safety form.
- 2. Measure the mass of each coin.
- **3.** Mark a line 2 cm from one end of the cardboard strip. Label this line *Output*.
- **4.** Slide the other end of the cardboard strip over the edge of a table until the strip begins to tip. Mark a line across the strip at the table edge and label this line *Input*.
- **5. Measure** the mass of the strip to the nearest 0.1 g. Write this mass on the input line.
- **6.** Center a dime on the output line. Slide the cardboard strip until it begins to tip. Mark the balance line. Label it *Fulcrum 1*.



- **7. Measure** the lengths of the output and input arms to the nearest 0.1 cm.
- **8.** Calculate the *IMA* of the lever. Multiply the *IMA* by the mass of the lever to find the approximate mass of the coin.
- **9.** Repeat steps 6 through 8 with the nickel and the quarter. Mark the fulcrum line *Fulcrum 2* for the nickel and *Fulcrum 3* for the quarter.

## Conclude and Apply

- **1. Explain** why there might be a difference between the mass of each coin measured by the balance and the mass measured using the lever.
- **2. Explain** what provides the input and output forces for the lever.
- **3. Explain** why the *IMA* of the lever changes as the mass of the coin changes.



Compare your results with those of other students in your class. For more help, refer to the Science Skill Handbook.



## **Model and Invent**

## Using Simple Machines

#### Goals

- **Model** lifting devices based on a block and tackle and on an inclined plane.
- **Calculate** the output work that will be accomplished.
- **Measure** the force needed by each machine to lift a weight.
- **Calculate** the input work and efficiency for each model machine.
- **Select** the best machine for your job based on the force required.

#### **Possible Materials**

spring scale, 0—10 N range 9.8-N weight (1-kg mass) double pulley single pulley string for the pulleys stand or support for the pulleys wooden board, 40 cm long support for board, 10 cm high

#### **Safety Precautions**



## Real-World Problem

Suppose that you are the contractor on a one-story building with a large air conditioner. How can you get the air conditioner to the roof? How can you minimize the force needed to lift an object? What machines could you use? Consider a fixed pulley, a block and tackle system of pulleys, and an inclined plane. How can you find the efficiency of machines?

## Make a Model

- 1. Complete the safety form.
- **2.** Work in teams of at least two. **Collect** all the needed equipment.
- **3.** Sketch a model for each lifting machine. Include a control in which the weight is lifted while being suspended directly from the spring scale. Model the inclined plane with a board 40-cm long and raised 10 cm at one end.
- **4.** Make a data table like the one below.
- 5. Is the pulley support high enough that the block and tackle can lift a weight 10 cm?
- **6.** Obtain your teacher's approval of your sketches and data table before proceeding.

Problem Data				
	Control	Inclined Plane	Block and Tackle	
Ideal Mechanical Advantage, IMA	1			
Input force, F <sub>in</sub> , N		Do no	t write	
Input distance, d <sub>in'</sub> m	0.10	in thi	s book.	
Output force, F <sub>out</sub> , N	9.8	9.8	9.8	
Output distance, d <sub>out</sub> , m	0.10	0.10	0.10	
$Work_{in} = F_{in} d_{in'}$ Joules				
$Work_{out} = F_{out} d_{out}$ Joules	0.98	0.98	0.98	
Efficiency = $(Work_{out}/Work_{in}) \times 100\%$				

## Using Scientific Methods

## Test Your Model

- **1.** Tie the weight to the spring scale and measure the force required to lift it. Record the input force in your data table under *Control*, along with the 10-cm input distance.
- **2.** Assemble the inclined plane so that the weight can be pulled up the ramp at a constant rate. The 40-cm board should be supported so that one end is 10 cm higher than the other end.
- **3.** Tie the string to the spring scale and measure the force required to move the weight up the ramp at a constant speed. Record this input force under *Inclined Plane* in your data table. Record 40 cm as the input distance for the inclined plane.
- **4.** Assemble the block and tackle using one fixed double pulley and one movable single pulley.
- **5.** Tie the weight to the single pulley and tie the spring scale to the string at the top of the upper double pulley.
- **6. Measure** the force required to lift the weight with the block and tackle. Record this input force.
- **7. Measure** the length of string that must be pulled to raise the weight 10 cm. Record this input distance.

## Analyze Your Data

- **1. Calculate** the output work for all three methods of lifting the 9.8-N weight a distance of 10 cm.
- **2. Calculate** the input work and the efficiency for the control, the inclined plane, and the block and tackle.
- **3. Compare** the efficiencies of each of the three methods of lifting.

## Conclude and Apply

- **1. Explain** how you might improve the efficiency of the machine in each case.
- Infer what types of situations would require the use of a ramp over a pulley to help lift something.
- **3. Infer** which machines would be most likely to be affected by friction.





Make a poster showing how the best machine would be used to lift the air conditioner to the roof of the building.

# TIME

# SCIENCE AND SOCIETY

SCIENCE ISSUES THAT AFFECT YOU!

# The Science of very, very small

magine an army of tiny robots, each no bigger than a bacterium swimming through your bloodstream.

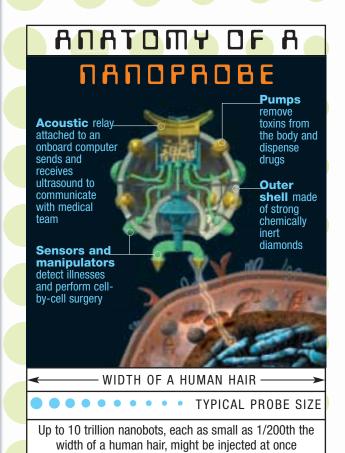
Welcome to the world of nanotechnology, the science of creating molecular-sized machines. These machines are called nanobots. This is the smallest guitar in the world. It is about as big as a human white blood cell. Each of its six silicon strings is 100 atoms wide. You can see the guitar only with an electron microscope.

The smallest of these machines are only billionths of a meter in size. They are so tiny that they can do work on the molecular scale.

## **Small, Smaller, Smallest**

Nanotechnologists are predicting that within a few decades they will be creating nanobots that can do just about anything, as long as it's small. Already, nanotechnologists have built gears 10,000 times thinner than a human hair. They've also built tiny molecular "motors" only 50 atoms long. At Cornell University, nanotechnologists created the world's smallest guitar. It is appoximately the size of a white blood cell and it even has six strings.

In the future, nanobots might transmit your internal vital signs to a nanocomputer implanted under your skin. There the data could be analyzed for signs of disease. Other nanomachines then could be sent to scrub your arteries clean of dangerous blockages, or mop up cancer cells, or even vaporize blood clots with tiny lasers. These are just some of the possibilities in the imaginations of those studying the new science of nanotechnology.



**Design** Think up a very small simple or complex machine that could go inside the body and do something. What would the machine do? Where would it go? Share your diagram or design with your classmates.

TIME
For more information, visit gpescience.com

## **Reviewing Main Ideas**

#### Section 1 Work

- **1.** Work is the energy transferred when a force makes an object move.
- **2.** Work is done only when a force produces motion in the direction of the force.
- **3.** Power is the amount of work, or the amount of energy transferred, in a certain amount of time.



#### Section 2 **Using Machines**

1. A machine makes work easier by changing the size of the force applied, by increasing the distance an object is moved, or by changing the



- direction of the applied force. **2.** The number of times a machine multiplies
- the force applied to it is the mechanical advantage of the machine. The actual mechanical advantage is always less than the ideal mechanical advantage.

- **3.** The efficiency of a machine equals the output work divided by the input work.
- **4.** Friction always causes the output work to be less than the input work, so no real machine can be 100 percent efficient.

#### Section 3 **Simple Machines**

- **1.** A simple machine is a machine that can do work with a single movement.
- 2. A simple machine can increase an applied force, change its direction, or both.
- **3.** A lever is a bar that is free to pivot about a fixed point called a fulcrum. A pulley is a grooved wheel with a rope running along the groove. A wheel and axle consists of two different-sized wheels that rotate together. An inclined plane is a sloping surface used to raise objects. The screw and the wedge are special types of inclined planes.
- **4.** A combination of two or more simple machines is called a compound machine.



FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review how machines make doing work easier.

#### **Using Vocabulary**

compound machine p. 174 output force p. 162 efficiency p. 164 power p. 157 inclined plane p. 172 pulley p. 169 input force p. 162 screw p. 173 lever p. 166 simple machine p. 166 machine p. 160 wedge p. 173 mechanical advantage wheel and axle p. 171 p. 164 work p. 154

Complete each statement using a word(s) from the vocabulary list above.

- **1.** A combination of two or more simple machines is a(n) \_\_\_\_\_.
- **2.** A wedge is another form of a(n) \_\_\_\_\_
- **3.** The ratio of the output force to the input force is the \_\_\_\_\_ of a machine.
- **4.** A(n) \_\_\_\_\_\_ is a grooved wheel with a rope, chain, or cable in the groove.
- **5.** The force exerted by a machine is the
- **6.** Energy is transferred when \_\_\_\_\_ is done.
- **7.** \_\_\_\_\_ is the rate at which work is done or energy is transferred.

#### **Checking Concepts**

Choose the word or phrase that best answers the question.

- **8.** Which of these is not done by a machine?
  - A) multiply force
  - **B)** multiply energy
  - **c)** change direction of a force
  - **D)** work
- **9.** Which of the following increases as the efficiency of a machine increases?
  - A) work input
- **c)** friction
- **B)** work output
- D) IMA

- **10.** In an ideal machine, which of the following is true?
  - **A)** Work input is equal to work output.
  - **B)** Work input is greater than work output.
  - **C)** Work input is less than work output.
  - **D)** The *IMA* is always equal to one.

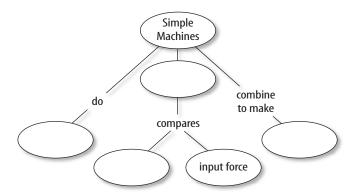
Use the picture below to answer question 11.



- **11.** What simple machines make up a pair of scissors?
  - **A)** lever and pulley
  - **B)** pulley and wheel and axle
  - **C)** wedge and pulley
  - **D)** wedge and lever
- **12.** What term indicates the number of times a machine multiplies the input force?
  - **A)** efficiency
  - **B)** power
  - **c)** mechanical advantage
  - **D)** resistance
- **13.** How could you increase the *IMA* of an inclined plane?
  - A) increase its length
  - B) increase its height
  - **c)** decrease its length
  - **D)** make its surface smoother
- **14.** What is the *IMA* of a screwdriver with a shaft radius of 3 mm and a handle radius of 10 mm?
  - **A)** 0.3
- **c)** 30
- **B)** 3.3
- **D)** 13
- **15.** What is the *IMA* of an inclined plane that is 2.1 m long and 0.7 m high?
  - **A)** 0.3
- **c)** 1.5
- **B)** 2.8
- **D)** 3.0

## **Interpreting Graphics**

**16.** Copy and complete the concept map of simple machines using the following terms: compound machines, mechanical advantage, output force, work.



Use the table below to answer questions 17 and 18.

Lever Input and Output Arms			
Lever	Input Arm (cm)	Output Arm (cm)	
А	25	75	
В	53	42	
C	36	36	
D	32	99	
E	10	30	

- 17. Determine which of the levers listed in the table above has the largest *IMA*.
- **18.** Calculate An input force of 50 N is applied to lever B. If the lever is 100 percent efficient, what is the output force?

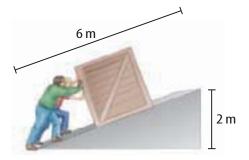
## **Thinking Critically**

**19. Describe** how the input force, output force, and fulcrum should be arranged so that a child can lift an adult using his own body weight on a seesaw.

- **20. Determine** what arrangement of movable and fixed pulleys would give a mechanical advantage of 3.
- **21.** Explain which would give the best mechanical advantage for driving a screw down into a board: a screwdriver with a long, thin handle, or a screwdriver with a short, thick handle.

#### **Applying Math**

- **22.** Calculate Work Find the work needed to lift a 20.0-N book 2.0 m.
- 23. Calculate Axle Radius A doorknob has an *IMA* equal to 8.5. If the diameter of the doorknob is 8.0 cm, what is the radius of the shaft the doorknob is connected to?
- **24.** Calculate Input Work A machine has an efficiency of 61 percent. Find the input work if the output work is 140 J.
- **25.** Calculate Efficiency Using a ramp 6 m long, workers apply an input force of 1,250 N to move a 2,000-N crate onto a platform 2 m high. What is the efficiency of the ramp?



**26.** Calculate Power A person weighing 500 N climbs 3 m. How much power is needed to make the climb in 5 s?

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### Multiple Choice

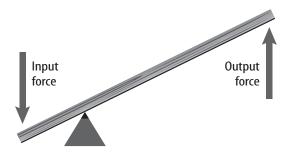
Use the figure below to answer questions 1 and 2.



- **1.** The figure above shows a doorknob with a radius of 4.8 cm and a mechanical advantage of 4.0. What is the radius of the inner rod that connects the knob to the door?
  - **A.** 0.6 cm
  - **B.** 1.2 cm
  - **c.** 1.8 cm
  - **D.** 2.4 cm
- 2. What would happen to the mechanical advantage if the radius of the doorknob were doubled?
  - **A.** It would be multiplied by 4.
  - **B.** It would be multiplied by 2.
  - **c.** It would be divided by 4.
  - **D.** It would be divided by 2.
- **3.** A ramp is 2.8 m long and 1.2 m high. How much power is needed to push a box up the ramp in 4.6 s with a force of 96 N?
  - **A.** 21 W
  - **B.** 25 W
  - **c.** 58 W
  - **D.** 270 W

- **4.** How much work is done in lifting a 9.10-kg box onto a shelf 1.80 m high?
  - **A.** 5.06 J
  - **B.** 16.4 J
  - **c.** 49.5 J
  - **D.** 161 J
- **5.** An input force of 80 N is used to lift an object weighing 240 N with a system of pulleys. How far down must the rope around the pulleys be pulled to lift the object a distance of 1.4 m?
  - **A.** 0.47 m
  - **B.** 1.4 m
  - **c.** 2.8 m
  - **D.** 4.2 m

Use the figure below to answer questions 6 and 7.



- **6.** If a lever's input arm is 8 cm and its output arm is 24 cm, what is the ideal mechanical advantage of the lever?
  - **A.** 4
  - **B.** 3
  - **c.** 0.33
  - **D.** 0.25

#### Gridded Response

- 7. How much more work is done to push a box 2.5 m with a force of 30 N than to push a box 2.0 m with a force of 26 N?
- **8.** As you throw a ball, you exert a force of 4.2 N on the ball. You exert this force on the ball while the ball moves a distance of 0.45 m. The ball leaves your hand and travels a horizontal distance of 8.5 m to your friend. How much work have you done on the ball?

#### Short Response

Use the illustration below to answer questions 9 and 10.



- **9.** What is the ideal mechanical advantage of the pulley system shown in the figure above?
- **10.** If the block supported by the pulley system has a weight of 20 N, what is the input force on the rope?

#### Extended Response

**11.** Use the law of conservation of energy to explain why it is impossible for the output work of a machine to be greater than the machine's input work.

#### Use the illustration below to answer question 12.

**12.** The boy in the figure below is carrying a box to the top of the stairs.



- **PART A** Describe how the work that the boy does on the box is related to the energy transfer that occurs. How does the energy of the box change form as the boy carries the box up the stairs?
- **PART B** Explain how the work, power, and energy would change if the boy walked faster. How would the work, power, and energy change if the steps were the same height but steeper?

#### Test-Taking Tip

**Don't Panic** Stay calm during the test. If you feel yourself getting nervous, close your eyes and take five slow, deep breaths.

## chapter



#### BIG (Idea

Gravitational forces cause the Moon to orbit Earth and Earth to orbit the Sun.

#### 7.1 Earth in Space

MAIN (Idea Earth is a sphere that revolves around the Sun in an elliptical orbit.

#### 7.2 Time and Seasons

MAIN (Idea The tilt of Earth's rotation axis causes the change in seasons.

#### 7.3 Earth's Moon

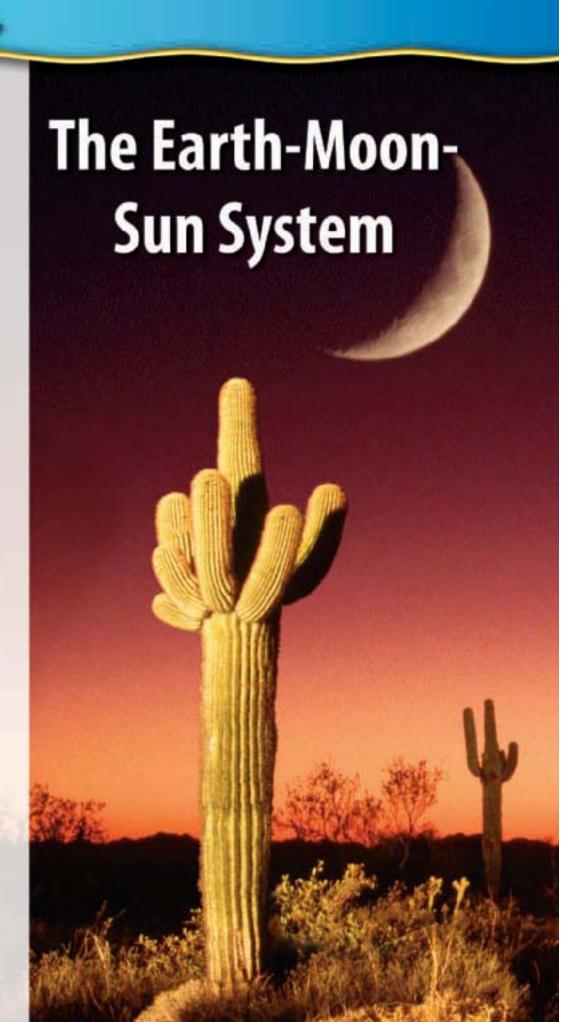
MAIN (Idea Phases of the Moon and eclipses are due to the motion of the Moon around Earth.

## Are there tides in a desert?

Did you know that the Moon exerts a gravitational pull on Earth? Tides in Earth's oceans and seas are caused mainly by the Moon's gravitational pull. The Moon's gravity also helps cause Earth's tectonic plates to flex. This causes very small up-and-down movements of solid land, similar to ocean tides, even in a desert.

#### **Science Journal**

Research to discover what landforms or events are affected by the Moon's gravitational force on Earth.



## **Start-Up Activities**



## Relative Sizes of Earth, the Moon, and the Sun

Can you picture the relative sizes of Earth, the Moon, and the Sun? Earth is about four times larger than the Moon in diameter, but the Sun is much larger than either. The Sun's diameter is about 100 times that of Earth and about 400 times that of the Moon. In this Lab, you'll investigate the relative sizes of all three objects.

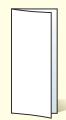
- Get permission to draw some circles on a sidewalk or paved area with chalk. You could also use a stick to draw circles on a dirt playing field.
- 2. Select a scale that will enable you to draw circles that will represent each object.

  Hint: Using 1 cm for the Moon's diameter is a good start.
- 3. Use a meterstick to draw a circle with a 1-cm diameter for the Moon.
- 4. Now draw two more circles to represent Earth and the Sun.
- 5. Think Critically In your Science Journal, explain how the Moon and the Sun can appear to be about the same size in the sky. Think about how things look smaller the farther they are from you.



**Earth, Sun, and Moon** Make the following Foldable to help organize what you learn about the Earth-Moon-Sun system.

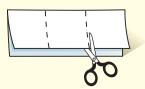
Fold a sheet of paper vertically from side to side. Make the front edge about  $\frac{1}{2}$  inch longer than the back edge.



STEP 2 Turn lengthwise and fold into thirds.



STEP 3 Unfold and cut only the top layer along both folds to make three tabs.



STEP 4 Label each tab.



**Questions** As you read the chapter, write what you learn about each body under the correct tab of your Foldable. After you read the chapter, note the many ways that the three affect each other.



Preview this chapter's content and activities at gpescience.com

# **Earth in Space**

## **Reading Guide**

## What You'll Learn

- Compare and contrast Earth's physical characteristics with those of other planets.
- **Explain** Earth's magnetic field.
- **Describe** Earth's movement in space and how eclipses occur.

## Why It's Important

Gravity from the Earth-Moon-Sun system directly affects what it's like to live here on Earth.

#### Review Vocabulary

orbit: curved path of one object, such as the Moon, around another object, such as Earth

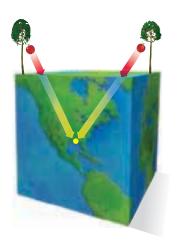
#### New Vocabulary

- sphere
- ellipse
- gravity

Figure 1 Objects fall toward Earth's center.

**Infer** How would apples fall from trees if Earth were shaped like a cube?





## **Earth's Size and Shape**

Like most people, you are aware that Earth is round like a ball. But can you prove that this is true? If you jump up, you know that you'll come back down, but why is this so? What is the force that brings you down? You may have used a compass to tell directions, but do you know how a compass works? You will learn the answers to these questions in this section. You will also learn about physical characteristics of Earth.

**Ancient Measurements** Earth's shape is similar to a sphere. A sphere is a round, three-dimensional object, the surface of which is the same distance from the center in all directions. Even ancient astronomers knew that Earth is spherical in shape. We have pictures of Earth from space that show that Earth is spherical, but how could astronomers from long ago have learned this? They used evidence from observations.

Aristotle was one of these early astronomers. He made three different observations that indicated that Earth's shape is spherical. First, as shown in **Figure 1**, no matter where you are on Earth, objects fall straight down to the surface, as if they are falling toward the center of a sphere. Second, Earth's shadow on the Moon during a lunar eclipse is always curved. If Earth weren't spherical, this might not always be the case. For example, a flat disk illuminated from the side would cast a shadow with straight edges. Aristotle's third observation was that people in different parts of the world see different stars at night. If Earth's surface were flat, everyone would see the same stars.

**Everyday Evidence of Earth's Shape** What have you seen, other than pictures from space, that shows Earth is a sphere? Think about walking toward someone over a hill. First, you see the top of the person's head, and then you can see more and more of that person. Similarly, if you sail toward a lighthouse, you first see the top of the lighthouse and then see more and more of it as you move over Earth's curved surface.

You can see other evidence, too. Just like ancient astronomers, you can see for yourself that objects always fall straight down. Today, however, we know more about gravity. **Gravity** is the attractive force between two objects that depends on the masses of the objects and the distance between them. Today astronomers think Earth formed as objects in the early solar system crashed into each other and clumped together because of their gravitational attraction for each other. Energy released as objects crashed into the growing Earth caused Earth to be molten. Gravity then caused the molten Earth to form a sphere. Because Earth is a sphere, the pull of gravity on objects near Earth's surface is always straight downward toward Earth's center. **Table 1** lists some other physical properties of Earth.



How does the pull of gravity indicate that Earth's shape is spherical?

Table 1 Earth's Physical Properties		
Diameter (pole to pole)	12,714 km	
Diameter (through equator)	12,756 km	
Circumference (poles)	40,008 km	
Circumference (equator)	40,075 km	
Mass	$5.98  imes 10^{24} \mathrm{kg}$	
Average density	5.52 g/cm <sup>3</sup>	
Average distance to the Sun	149,600,000 km	
Average distance to the Moon	384,400 km	
Period of rotation	23 h, 56 min	
Period of revolution	365 days, 6 h, 9 min	



## Topic: Comparing Earth to Other Planets

Visit **gpescience.com** for Web links to information about how Earth is similar to and different from other planets in the solar system.

**Activity** Make a table that lists the similarities and differences of Mercury, Venus, Earth, and Mars.



Van Allen Belts The magnetosphere lies above the outer layers of Earth's atmosphere. Within this magnetosphere are belts of charged particles known as the Van Allen belts. They contain thin plasma composed of protons (inner belt) and electrons (outer belt) that are trapped by Earth's magnetic field. Research how the magnetosphere protects Earth from the solar wind and why the Van Allen belts are hazardous to astronauts and satellites. Report your findings to the class.

**Figure 2** Like a common bar magnet, Earth also has north and south magnetic poles. The inner and outer gold shells respectively represent the positive and negative Van Allen Belts.

**Explain** why the Van Allen Belts are shaped as they are.

## **Earth's Magnetic Field**

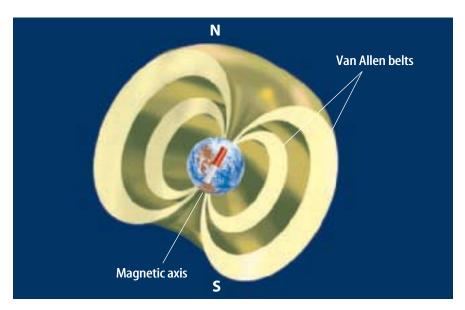
Earth has a magnetic field that protects us from harmful radiation from the Sun. Scientists hypothesize that Earth's rotation and movement of matter in the core set up a strong magnetic field in and around Earth. This field resembles that surrounding a bar magnet, shown in **Figure 2.** Earth's magnetic field is concentrated at two ends of an imaginary magnetic axis running from Earth's north magnetic pole to its south magnetic pole. This axis is tilted about 11.5° from Earth's geographic axis of rotation.

**Wandering Poles** The locations of Earth's magnetic poles change slowly over time. Large-scale movements, called polar wandering, are thought to be caused by movements in Earth's crust and upper mantle. The magnetic north pole is carefully remapped periodically to pinpoint its location.

The Aurora An area within Earth's magnetic field, called the magnetosphere, deflects harmful radiation coming from the Sun, a stream of particles called the solar wind. Some of these ejected particles from the Sun produce other charged particles in Earth's outer atmosphere. These charged particles spiral along Earth's magnetic field lines toward Earth's magnetic poles. There they collide with atoms in the atmosphere. These collisions cause the atoms to emit light. This light is called the aurora borealis (northern lights) in the northern hemisphere and the aurora australis (southern lights) in the southern hemisphere.

#### **Earth Orbits the Sun**

Earth orbits the Sun at an average distance of 149,600,000 km. Its orbit, like those of all the planets, moons,



asteroids, and many comets, is shaped like an ellipse. An ellipse is an elongated, closed curve with two foci. The Sun is not located at the center of the ellipse, but at one of its two foci. This means the distance from Earth to the Sun varies during the year. Earth is closest to the Sun—about 147 million km away—around January 3 and is farthest from the Sun—about 152 million km away—around July 4 of each year.

**Earth as a Planet** Earth is one of the eight planets in the solar system. However, Earth is the only planet whose characteristics make it possible for life as we know it to survive.

For example, Venus is nearly the same size as Earth, but conditions on the surfaces of the two planets are very different. Venus's atmosphere is about 96 percent carbon dioxide, while Earth's atmosphere contains only about 0.04 percent carbon dioxide. One reason Earth's atmosphere contains so much less carbon dioxide is that Earth's oceans, shown in **Figure 3**, absorbed much of the carbon dioxide in Earth's early atmosphere.

The large amount of carbon dioxide in Venus's atmosphere traps some of the heat energy given off by the planet and prevents it from escaping into space. This effect, called the greenhouse effect, causes the average surface temperature on Venus to be over 460°C. Other gases, such as water vapor, also cause a greenhouse effect. On Earth, where the amount of atmospheric greenhouse gases is much lower, the greenhouse effect is much less. As a result, Earth's average surface temperature is about 15°C.



What feature of Earth's surface has led to such a difference between Earth and Venus?

Mars is about half the size of Earth, and its surface gravitational pull is only about 38 percent as strong as Earth's. This weak gravitational pull is not strong enough to hold a dense atmosphere around the planet. As a result, Mars's atmosphere is only about 1.6 percent as dense as Earth's atmosphere and its average surface temperature is about -63°C.



**Figure 3** By absorbing carbon dioxide, oceans protect Earth from experiencing a greenhouse effect like that on Venus.

#### section

## review

#### **Summary**

#### Earth's Size and Shape

- Earth has a spherical shape.
- Gravity causes very large objects in space to form spheres.

#### **Earth's Magnetic Field**

- Earth's magnetic field protects life on Earth's surface from harmful radiation.
- Interaction of the solar wind with Earth's magnetic field produces the aurora.

#### **Earth Orbits the Sun**

- Earth orbits the Sun in an elliptical orbit.
- Earth and Venus are similar in size, and both have atmospheres that contain carbon dioxide.

#### **Self Check**

- Identify two pieces of evidence that prove Earth's spherical shape.
- **2. Define** the term *gravity*.
- 3. Explain what produces Earth's magnetic field.
- 4. **Describe** how Venus and Earth are similar.
- Think Critically Evidence indicates that Mars once had liquid water on its surface. Discuss some possible reasons why it has none today.

#### **Applying Math**

6. Calculate Speed Earth's circumference at the equator is 40,075 km. If it spins once each day, what is the speed of spinning in km/h?

## **Time and Seasons**

## **Reading Guide**

## **What** You'll Learn

- Calculate the time and date in different time zones.
- Differentiate between revolution and rotation.
- Discuss what causes seasons to change.

## Why It's Important

Days and years are measurements of Earth's movements.

#### Review Vocabulary

latitude: angular distance north or south of Earth's equator

#### New Vocabulary

- time zone
- rotation
- revolution
- ecliptic
- equinox
- solstice

## **Measuring Time on Earth**

People can determine the approximate time of day by determining where the Sun is in the sky. If the Sun is near an imaginary line drawn from due north to due south, it is about 12:00 noon. Humans have used movements of Earth, the Moon, and the Sun to measure time for thousands of years.

Around 3000 B.C., the Babylonians devised a method of timekeeping using their counting methods, which were based on 60. They noticed that the Sun appeared to take a circular path through the sky. Because their counting methods were based on 60, they divided a circle into 360 parts called degrees. The symbol for degree (°) was taken from their symbol for the Sun.

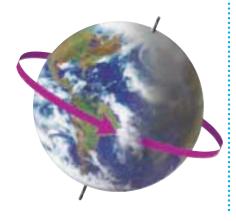
**Earth Movements Measure Time** Earth spins and makes one complete turn in about 24 hours, as shown in **Figure 4.** This spinning causes the Sun to appear to move across the sky from east to west. It takes 24 hours from when the Sun is highest in the sky (noon) until it is highest in the sky again (noon the next day).

If Earth spins approximately 360° in 24 hours, then it spins through 15° in one hour. This led to the setting up of time zones on Earth that have the same time in minutes but vary in hours. A **time zone** is an area 15° wide in which the time is the same. **Figure 5** shows the time zones in the U.S. Ideally, time zones should be equal in size and follow lines drawn from the north pole to the south pole. However, for convenience, time zones are modified to fit around city, state, and country borders, and other key sites.



Reading Check How many degrees does Earth spin in one hour?

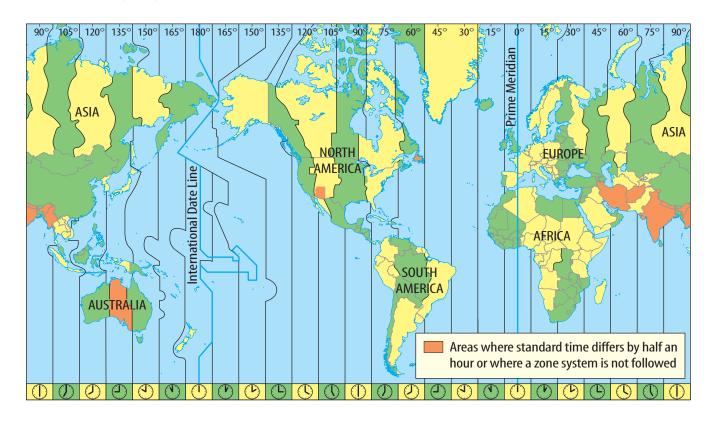
**Figure 4** The sunlit side of Earth is day; the shadow side is night.



**The Date Line** You can see that a problem would quickly arise if you just kept dropping back an hour earlier for each 15°. Eventually, you would come around Earth and it would be 24 hours earlier. It cannot be two different days at the same spot, so a day is added to the time at the International Date Line. If it is Monday to the east of the date line, then it is the same hour on Tuesday to the west of the date line. This line is drawn down through the Pacific Ocean (around islands, such as New Zealand) directly opposite the Prime Meridian, the starting point for this worldwide system of measuring time. The Prime Meridian is an imaginary line drawn on Earth that passes through Greenwich, England. Time based on this method is called Coordinated Universal Time (UTC). In some areas, this time is modified in summer so that there are more hours of daylight in the evening. This is referred to as Daylight Saving Time (DST). Some areas apply local modifications to this system as well.

**Figure 5** The globe is divided into 24 time zones. Lines of longitude roughly determine the locations of time zone boundaries. Notice that each successive time zone to the west is one hour earlier.

**Think Critically** If you leave Russia at 12:30 A.M. on Tuesday and fly east for one hour across the Bering Strait, what time and day will you arrive in Alaska?



**Rotation Measures Days** The spinning motion of Earth enables you to measure the passing hours of the day. Rotation is the spinning of Earth on its axis, an imaginary line drawn through Earth from its rotational north pole to its rotational south pole.

The apparent movement of the Sun from noon one day until noon the next day is called a solar day. This period is a bit longer than the time it takes Earth to rotate on its axis, however. This is because while Earth rotates, it also moves in its orbit around the Sun and must rotate a bit more each day to make the Sun reach noon. However, if you measure time based on when a certain star rises above the horizon until it rises again, you will see a slightly shorter time period (23 h 56 m 4 s). This is called a sidereal day and is the true measure of the time it takes for Earth to rotate once on its axis.

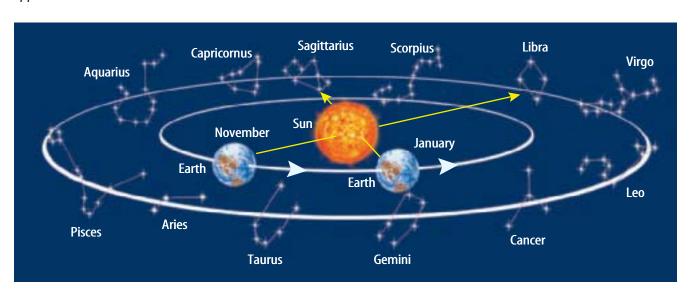
**Revolution Measures Years** The motion of Earth around the Sun enables you to measure the passing of years. **Revolution** is the motion of Earth in its orbit around the Sun. Figure 6 shows Earth's orbit around the Sun. As Earth revolves in its orbit, the Sun appears to move through the skies compared to the seemingly fixed positions of the stars.

The time it takes for the Sun to make one complete trip through the sky in reference to the background of stars is the same amount of time it takes for Earth to complete one trip around the Sun, or one sidereal year. The apparent path of the Sun during this year is called the ecliptic. Also, the ecliptic is defined as the plane of Earth's orbit around the Sun. The 12 constellations (star patterns) through which we observe the Sun moving during this year is called the zodiac, shown in **Figure 6.** 

Reading Check What is the ecliptic?

**Figure 6** If the Sun were as faint as the stars at night, then you would see it travel along an annual path through the constellations of the Zodiac.

**Think Critically** What causes this apparent motion of the Sun?



## Why do seasons change?

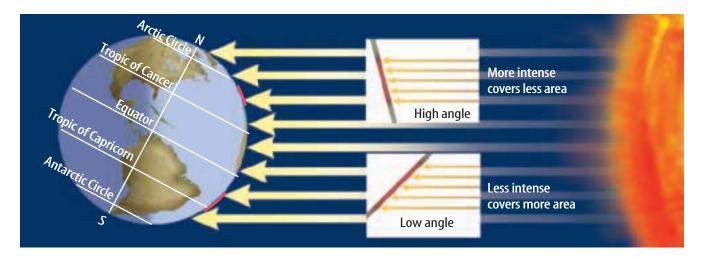
Recall that Earth's orbit around the Sun is an ellipse. This means that Earth is closer to the Sun at one time than it is at other times. Is this the cause of seasonal changes on Earth? Because Earth is closest to the Sun in January, you would expect this to be the warmest month. However, you know this isn't true in the northern hemisphere; something else must be causing the change. These seasonal changes are due to the tilt of Earth's rotational axis.

Earth's axis is tilted 23.5° from a line perpendicular to the plane of its orbit. Because of this tilt, Earth's geographic north pole points toward the star Polaris. The tilt of Earth's rotation axis causes the angle at which the Sun's rays strike Earth's surface to vary through the year. The tilt also causes the number of hours of daylight to vary. It is these variations, caused by the tilt of Earth's axis, that cause seasons to change.

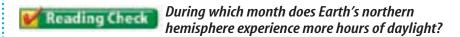
**Changing Angle of Sunlight** During mid-summer in the northern hemisphere, the Sun is higher in the sky throughout most of the day compared to other times of the year. The Sun is lowest in the sky during mid-winter. As a result, in the northern hemisphere the Sun's rays strike Earth's surface at a higher angle during the summer than during the winter. Sunlight is more intense and warms Earth's surface more when striking the surface at higher angles than at lower angles.

Earth's rotational axis always points in the same direction as Earth revolves around the Sun. This causes the northern and southern hemispheres to be tilted toward the Sun at different times of the year. As shown in Figure 7, the hemisphere tilted toward the Sun receives sunlight at higher angles than the hemisphere tilted away from the Sun. Figure 7 also shows that when it is summer in the northern hemisphere, it is winter in the southern hemisphere.

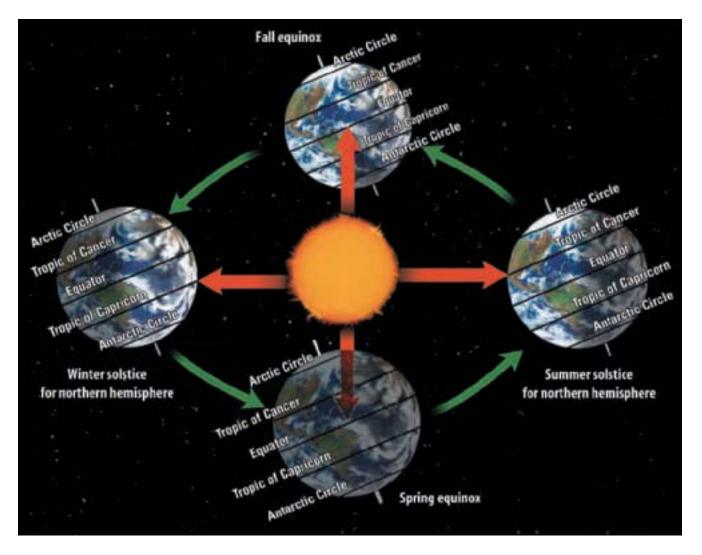
**Figure 7** The Sun's rays strike Earth's surface at higher angles in the northern hemisphere when the north pole is tilted toward the Sun.



More Hours of Daylight in Summer During the summer, the Sun is above the horizon for more hours than it is when school begins in the fall. As the year progresses, the number of hours of daylight each day becomes fewer and fewer until it reaches a minimum around December 21 for the northern hemisphere. When do you think the number of hours of daylight would be at a maximum in the northern hemisphere? This happens six months later, around June 21. As shown in **Figure 8**, the hemisphere of Earth that is tilted toward the Sun receives more hours of daylight each day than the hemisphere tilted away from the Sun. This longer period of daylight is the second reason why summer is warmer than winter.



**Figure 8** During the winter solstice for the northern hemisphere, Earth's rotation axis points directly away from the Sun and the area within the arctic circle remains in darkness. During the summer solstice, Earth's rotation axis points directly toward the Sun and the area within the arctic circle remains in sunlight.



**Equinoxes** Earth's rotation axis always points toward the same direction in space—toward the star Polaris. As shown in Figure 8, the movement of Earth around the Sun causes Earth's axis to point toward the Sun in summer and away from the Sun in winter. However, as **Figure 8** also shows, there are two times during the year when Earth's axis doesn't point toward or away from the Sun. At an **equinox** Earth's axis is perpendicular to a line drawn from the center of Earth to the center of the Sun. During the spring and fall equinoxes, the number of daylight hours and nighttime hours are nearly the same all over the world. In the northern hemisphere, the spring equinox occurs on March 20 or 21, and the fall equinox occurs on September 22 or 23. In the southern hemisphere, the occurrence of the two equinoxes is reversed.

**Solstices** A **solstice** occurs when Earth's rotation axis is tilted directly toward the Sun or away from the Sun. In the northern hemisphere, the summer solstice occurs on June 21 or 22 when Earth's axis is tilted directly toward the Sun. The winter solstice occurs on December 21 or 22 when Earth's axis is tilted directly away from the Sun. Around the summer solstice, there are more hours of daylight than at any other time of the year. Then the Sun's rays strike the surface in the northern hemisphere at a high angle. Around the winter solstice, there are fewer hours of daylight than at any other time of the year. Then the Sun's rays strike the surface at a low angle. In the southern hemisphere, the occurrence of the winter and summer solstices is reversed.



# **Modeling the Sun's Rays at Solstice**

# Procedure

- 1. Use a **globe** with the equator, the Tropic of Cancer, and the Tropic of Capricorn indicated.
- **2.** Set up a light source, such as a flashlight or goose**neck lamp**, so light shines vertically at Earth's equator.
- 3. Tilt the globe 23.5° from vertical so that first the northern and then the southern hemisphere is tilted toward the light.

# **Analysis**

- 1. When the globe was tilted 23.5° toward and away from the light, what latitudes received vertical rays?
- 2. What areas of Earth never received vertical rays?

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# **Summary**

# **Measuring Time on Earth**

- Humans use movements of Earth, the Moon, and the Sun to measure time.
- Earth's rotation is used to measure days.
- Earth's revolution is used to measure years.
- The ecliptic is the Sun's apparent yearly path through the zodiac.

# Why do seasons change?

- Earth's seasonal changes are caused by the tilt of Earth's rotation axis.
- Equinoxes occur when Earth's axis is perpendicular to a line between Earth and the Sun. Solstices occur when Earth's axis points directly toward or away from the Sun.

## Self-Check

- 1. **Determine** how long it takes Earth to make one complete turn on its axis.
- **2. Explain** why each time zone contains 15° of longitude. If it is 4:15 P.M. in one time zone, what is the time two time zones to the west?
- 3. Explain how a solar day differs from a sidereal day.
- 4. Compare and contrast rotation and revolution.
- 5. Think Critically Why does Earth's surface become warmer in summer than it does in winter?

# **Applying Math**

**6. Use Decimals** It takes Earth about 365.25 days to make one trip around the Sun. As it does this, Earth travels 360° in its orbit. On average, how many degrees does Earth travel each day?



# Comparing the Angle of Sunlight to Intensity

Earth is warmed differently depending on the angle at which sunlight strikes it.



How can you a model the angle at which sunlight strikes Earth's surface?

### Goals

- **Model** different angles at which sunlight strikes Earth's surface.
- **Compare and contrast** the amount of heat generated by light striking at different angles.

#### **Materials**

75-W bulb in a gooseneck lamp alcohol thermometers (2) sheets of construction paper, one color (2) protractor

- \* unshaded 75-W lamp
- \* books to change the angle of the thermometers
- \*Alternate materials

# **Safety Precautions**



**WARNING:** Do not touch lamp or lightbulb without safety gloves. They stay hot after being turned off. Handle thermometers carefully.

# Procedure

- 1. Copy the data table shown on this page.
- **2.** Label the thermometers *T-1* and *T-2* and record their temperatures in the data table.
- **3.** Fold the construction paper to form a pocket that will conceal the thermometer's bulb.



- **4.** Place *T-1* in the pocket and lay them on a desktop. Turn on the lamp. Position the lamp so that light strikes the pocket at an angle of 75°.
- **5.** Record the temperature of *T-1* at 10 min and at 20 min.
- **6.** Repeat steps 3, 4, and 5 using *T-2*, but aim the lamp at an angle of 20°.

# Conclude and Apply

- **1. Compare and contrast** the temperature readings of each thermometer.
- **2. Infer** which angle models the Sun's position during the summer and during the winter.
- **3. Explain** how changes in the angle at which sunlight strikes Earth's surface are one cause of Earth's changing seasons.

Data Table				
Thermometer	Original Temperature	Temperature at 10 min	Temperature at 20 min	
T-1				
T-2				

# Communicating Your Data

Compile your classmates' data. Find the average temperatures—original, at 10 min, and at 20 min—for *T-1* and *T-2*. Compare and contrast your results with the class averages.

# Earth's Moon

# **Reading Guide**

# What You'll Learn

- Describe how tides on Earth are caused by the Moon.
- **Explain** how the Moon's phases depend on the relative positions of the Sun, the Moon, and Earth.
- Compare and contrast solar and lunar eclipses.
- Analyze what surface features of the Moon reveal about its history.

# Why It's Important

The Moon is our nearest neighbor in space and affects Earth in many ways.

# Review Vocabulary

lava: molten rock

# New Vocabulary

- tide
- moon phase
- solar eclipse
- lunar eclipse
- maria
- regolith

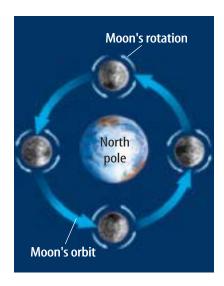
# **Movement of the Moon**

You have seen the Moon move across the sky from east to west, just like the Sun. This is an apparent movement like the Sun's, caused by Earth's rotation. But, the Moon actually does move in another way. If you look at the Moon each day at the same time over a period of a few days, you will see that it moves toward the east.

Rotation and Revolution This eastward movement of the Moon is an actual movement that is caused by the Moon's revolution in its orbit. It takes 27.3 days (a sidereal month) for the Moon to revolve once around Earth and line up with the same star again. Because Earth also revolves around the Sun, it takes more than two more days for the Moon to line up with Earth and the Sun again. This means that a complete lunar phase cycle takes 29.5 days, known as a synodic month.

Many people think the Moon does not rotate because it always keeps the same side facing Earth. This is not true. As shown in **Figure 9**, the Moon keeps the same side facing Earth because it takes 27.3 days to rotate once on its axis—the same amount of time that it takes to revolve once around Earth. You can observe this by having a friend move a ball around you while keeping the same side of it facing you. You will see only one side.

**Figure 9** The face of the "man in the moon" is always facing Earth. **Explain** why the same side of the Moon always faces Earth.



# **How does the Moon affect Earth?**

If you have ever been to the ocean shore, you probably have noticed that over a period of several hours, the height of the ocean seems to change. Twice a day, the water reaches its highest point on the shore, and then recedes to its lowest point on the shore. Over weeks and months, the heights of the highest and lowest levels vary. Also the times at which the high and low levels occur change throughout the year.

These daily changes in the height of the ocean are one way that the Moon affects Earth. These changes are caused by the gravitational forces that the Sun and Moon exert on Earth.

# **Applying Math**

# **Solve a Simple Equation**

**TIDES** The Moon rises an average of 52.7 min later each day. If the time of high tide is known for one day, this formula can be used to determine when high tide will occur on the next day or any successive day.

$$T_N = T_0 + N \times 52.7 \text{ min}$$

In this formula,  $T_0$  is the original time of high tide on a given day and  $T_N$  is the time of high tide on any successive day. N is the number of days later for which you wish to determine the time of high tide. If the tide is high at 1:00 P.M., find out what time it will be high in 7 days.

# **IDENTIFY** known values and unknown values

# Identify the known values:

 $T_0$  = original time of high tide = 1:00 P.M.

N = the number of days later for which you wish to determine high tide = 7

52.7 min = how much later the Moon rises each day

#### Identify the unknown value:

 $T_N$  = the time of high tide on N number of days

# **SOLVE** the problem

Substitute the known values into the equation for time.

$$T_N = 1:00 \text{ P.M.} + 7 \times 52.7 \text{ min} = 1:00 \text{ P.M.} + 369 \text{ min}$$

$$T_N = 1:00 \text{ p.m.} + 6 \text{ h } 09 \text{ min} = 7:09 \text{ p.m.}$$

# **Practice Problem**

Low tide is the best time to hunt for seashells. If you see that the tide is low at noon on Thursday, when during the day will it be low on the following Sunday?

For more practice problems, go to page 879 and visit Math Practice at gpescience.com.

**Tides** Think again of the beach and how the level of the sea rose and fell during the day. This rise and fall in sea level is called a **tide**. A tide on Earth is caused by a giant wave produced by the gravitational pulls of the Sun and the Moon. This wave has a wave height of only 1 or 2 m, but it has a wavelength of thousands of kilometers. As the crest of this large wave approaches the shore, the level of the water in the ocean rises. This rise of sea level is called high tide. About six hours later, as the trough of the wave approaches, sea level drops, causing a low tide.

The attractive gravitational force exerted by the Moon on water in an ocean depends on the distance of the water from the Moon. The closer the Moon is to the water, the stronger the Moon's pull. As a result, water on the side of Earth facing the Moon is pulled more strongly toward the Moon than water on Earth's opposite side. This causes two tidal bulges on Earth. One is on the side facing the Moon. The other is on the side opposite the Moon.

As Earth rotates and the Moon revolves, different locations on Earth's surface pass through the high and low tides. Although the Sun is much more massive than the Moon, it also is much farther away. Because of this, the Moon has a greater effect on Earth's tides than does the Sun. However, the Sun does affect Earth's tides: it can strengthen or weaken the moon's tidal effect. When the Moon and the Sun pull together, when they are lined up, high tides are much higher and low tides are much lower. This is called a spring tide, as shown in **Figure 10.** However, when the two are at right angles to each other, the high tide is not as high and the low tide not as low, producing a neap tide.

**Reading Checks** What happens to the sea level at spring tide?

# **Moonlight**

The Moon shines because it reflects sunlight from its surface. Just as half of Earth experiences day as the other half experiences night, half of the Moon is lighted while the other half is dark. As the Moon revolves around Earth, different portions of the side facing Earth are lighted, causing the Moon's appearance to change. **Moon phases** are the changing appearances of the Moon as seen from Earth. The phase you see depends on the relative positions of the Moon, Earth, and the Sun.

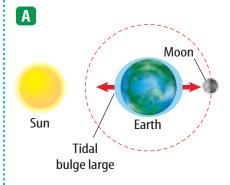
**Phases of the Moon** A new moon occurs when the Moon is between Earth and the Sun. During a new moon, the side of the Moon facing away from Earth is lighted and the side of the Moon facing Earth receives no light from the Sun. The Moon is in the sky, but it cannot be seen.

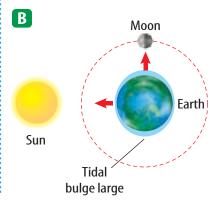
example of how the Sun, Moon, and Earth pull on each other and operate as a three-body system.

A The Sun, Earth, and Moon are in alignment during spring tide.

B The Sun, Earth, and Moon form a right angle during neap tide.

Identify whether high tide is higher during spring tide or neap tide.







# **Modeling Phases and Eclipses**

#### **Procedure**

# 

- 1. Turn on a lamp with no shade and place a small, white, plastic-foam ball on the end of a pencil.
- **2.** Stand facing the lamp and hold the white plasticfoam ball between your head and the lamp.
- 3. Slowly move the ball counterclockwise around your head and observe how much of the side of the ball facing you is lighted at different positions.
- 4. Note positions where the ball blocks light from the lamp—or moves into the shadow cast by your head.

#### **Analysis**

- 1. Describe what happened to the ball as it was moved around your head, and identify the moon phases at various positions.
- 2. At which positions (phases) was the ball blocking the light or falling into shadow? At which phase(s) can eclipses occur?

Figure 11 When viewed from Earth's north pole, the Moon has a counterclockwise orbit.

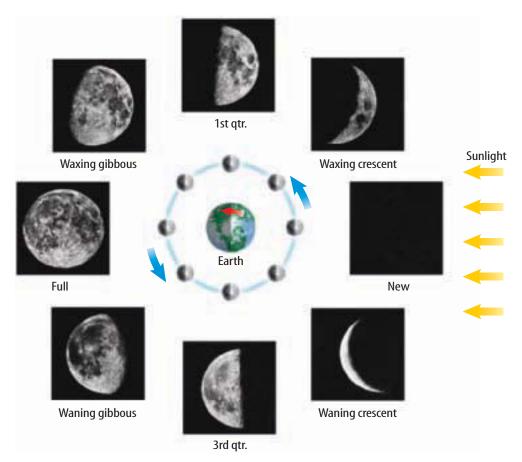
**Infer** *In this figure, the Sun's rays* are coming from the right. Why are the Moon's waning phases showing sunlight on the left?

**Waxing Phases** After a new moon, the moon's phases are said to be waxing—the lighted portion that we see appears larger each night. The first phase we see after a new moon is called the waxing crescent. About a week after a new moon, we see one-half of the Moon's lighted side, or one-quarter of the Moon's surface. This phase is the first-quarter.

The moon is in the waxing gibbous phase from the first quarter up until full moon. A full moon occurs when we see all of the Moon's lighted side. At this time, the Moon is on the side of Earth opposite from the Sun.

**Waning Phases** After a full moon, the lighted portion that we see begins to appear smaller. The phases are said to be waning. When only half of the side of the Moon facing Earth is lighted, the third-quarter phase occurs. The waning crescent occurs before another new moon. Only a small slice of the side of the Moon facing Earth is lighted.

The word *month* is derived from the same root word as *Moon*. The complete cycle of the Moon's phases, shown in Figure 11, takes about 29.5 days, or one synodic month. Recall that it takes about 27.3 days for the Moon to revolve around Earth. The discrepancy between these two numbers is due to Earth's revolution around the Sun. It takes the Moon a little over two days to "catch up" with Earth's advancement around the Sun.



# **Eclipses**

If you knew nothing about what the Sun is or why it produces so much light and heat,

wouldn't you be concerned if suddenly it darkened? Think of how humans from long ago must have reacted when the Moon passed in front of the Sun and the source of light and heat was blocked, as it is during an eclipse.

In the year 585 B.C., a battle was raging between the armies of the Lydians and the Persians when suddenly, the Sun was eclipsed by the Moon. The two armies were so stunned by the event that they put down their weapons and stopped fighting.

Now we understand what causes eclipses of both the Sun and the Moon. We know that for the Moon to block out the Sun, it must appear to be the same size. In fact, both the Sun and the Moon have apparent diameters when viewed from Earth that are almost the same, about 0.5°. If it weren't for this, a total eclipse of the Sun might never happen. Because the Sun is about 400 times larger than the Moon, it also must be about 400 times farther from Earth for a total solar eclipse to occur.

Eclipses occur when Earth or the Moon temporarily blocks sunlight from reaching the other object. Sometimes, during a new moon, a shadow cast by the Moon falls on Earth, causing a solar eclipse. During a full moon, a shadow of Earth can be cast on the Moon, resulting in a lunar eclipse. Eclipses can occur only when the Sun, the Moon, and Earth are lined up perfectly. Because the Moon's orbit is tilted about 5° from the plane of Earth's orbit around the Sun, eclipses happen only a few times each year.

**Solar Eclipses** A **solar eclipse** occurs when the Moon moves directly between the Sun and Earth and casts a shadow on part of Earth. The darkest portion of the Moon's shadow is called the umbra. A person standing within the umbra experiences a total solar eclipse. As shown in **Figure 12**, the only portion of the Sun that is visible during a total eclipse is part of its atmosphere, which

appears as a pearly white glow around the edge of the eclipsing Moon. This is the only time the entire disk of the new moon phase can be photographed—it appears black against the Sun.

As shown in **Figure 13**, surrounding the umbra is a lighter shadow on Earth's surface called the penumbra. Persons standing in the penumbra experience a partial solar eclipse. WARNING: Regardless of where you are standing, never look directly at a solar eclipse. The light can permanently damage your eyes.



How are Earth, the Moon, and the Sun aligned during a solar eclipse?



**Figure 12** The solar corona can be seen as a pale glow around the lunar disk. Sunlight shining through lunar valleys produces a diamond-ring effect.



**Early Civilizations** Celestial objects were studied by early civilizations. Some hypotheses proposed by the Babylonians and the early Greeks were close to reality, but other ideas were wrong. Research how some early civilizations explained eclipses and other astronomical observations and report your findings to your class using drawings and diagrams.

Figure 13 A total solar eclipse appears only within the Moon's umbra.

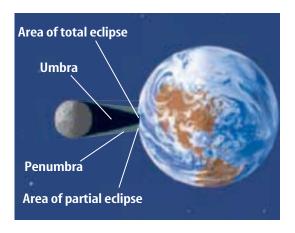




Figure 14 Sometimes during a partial lunar eclipse, Earth's curvature can be seen silhouetted on the Moon. The red coloration is caused by the refraction of sunlight passing through Earth's atmosphere before reaching the Moon's surface.

Lunar Eclipses When Earth's shadow falls on the Moon, a lunar eclipse occurs. A lunar eclipse begins when the Moon moves into Earth's penumbra. As the Moon continues to move, it enters Earth's umbra, and you see a curved shadow on the Moon's surface, as shown in **Figure 14.** It was this shadow that led Aristotle to conclude that Earth is spherical. When the Moon moves completely into Earth's umbra, a total lunar eclipse occurs, as shown in **Figure 15.** The Moon sometimes becomes red during an eclipse because light from the Sun is scattered and refracted by Earth's atmosphere. Longer wavelength red light is affected less than shorter wavelengths, so more red light falls on the Moon.

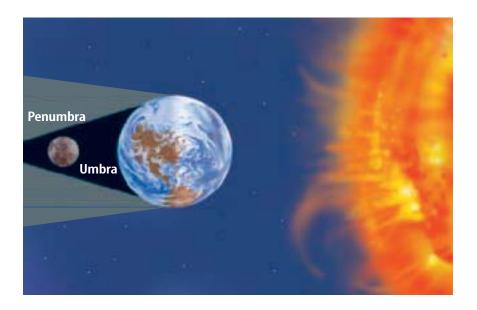
A partial lunar eclipse occurs when only a portion of the Moon moves into Earth's umbra. The remainder of the Moon is in Earth's penumbra and, therefore, receives some direct sunlight. A partial lunar eclipse also occurs when the Moon is partially or totally within Earth's penumbra. However, this can be difficult to see because some direct sunlight falls on the Moon, making it appear only slightly dimmer than usual.

A total solar eclipse can occur as often as twice a year, yet most people live their entire lives without witnessing one. You may never see a total solar eclipse, but it is almost certain you will have a chance to see a total lunar eclipse. The reason why it is so rare to view a total solar eclipse is that only those people in the small region where the Moon's umbra strikes Earth can see one and, even then, there must be clear skies. In contrast, the opportunities to witness lunar eclipses are much more frequent, and anyone on the night side of Earth can see them.



How are Earth, the Moon, and the Sun aligned during a lunar eclipse?

**Figure 15** A total lunar eclipse occurs when the Moon is entirely within Farth's umbra. Umbra is the Latin word for "shadow." Just as a peninsula is almost an island, a penumbra is almost a shadow. Research What does umbrella mean?



# **The Moon's Surface**

When you look at the Moon, as shown in **Figure 16**, you can see many of its larger surface features. Craters, rays, mountains, and maria can easily be seen through a small telescope or a pair of binoculars. What are these different features, how did they form, and what do they tell us about the Moon's history and interior?

**Craters, Maria, and Mountains** Many depressions on the Moon were formed by meteorites, asteroids, and comets, which strike the surfaces of planets and their satellites. These depressions, which are called craters, formed early in the Moon's history. Surrounding many craters are ray patterns produced by lighter-colored material from just below the lunar surface that was blasted out on impact. This lighter material then settled on top of the darker surface material around the craters. During the impact, when these large basins formed, cracks may have formed in the Moon's crust, allowing lava from the still-molten interior to reach the surface and fill in the basins, forming maria.

Maria are the dark-colored, relatively flat regions on the Moon's surface, shown in Figure 16. The igneous rocks of the maria are 3 to 4 billion years old. They are the youngest rocks found on the Moon so far. This indicates that the craters formed after the Moon's surface originally cooled. However, the maria formed early enough in the Moon's history that molten rock material still remained in the Moon's interior.

Surrounding the large depressions that later filled with lava are areas that were thrown upward in the original collisions and formed mountains. The largest mountain ranges on the Moon surround the large, flat, dark-colored maria.

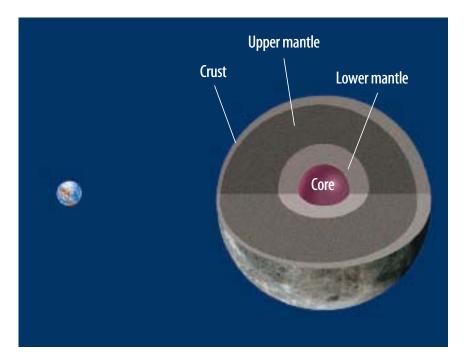
**Regolith** When NASA scientists started to plan for crewed spacecraft to land on the Moon, they were concerned about whether the lunar surface would be able to support the craft. To find out, unmanned Surveyor spacecraft were landed on its surface. One Surveyor craft actually bounced a few times as it landed on the side of a crater. What was this material that the spacecraft had landed on?

Impacts on the Moon thoughout its history led to the accumulation of debris known as regolith. On some areas of the Moon, this regolith is almost 40 m thick, while in other locations, it is only a few centimeters thick. Some regolith is coarse, but some is a fine dust. If you watch astronauts walking on the Moon, you will notice that they often kick up a lot of dust.

Figure 16 Notice the lightcolored material radiating outward

from the large crater near the base of the Moon.

**Identify** What are the flat, darkcolored regions called? What are the light-colored areas radiating from the craters called?



**Figure 17** The Moon's crust is thinnest on the side nearest to Earth.

**Infer** Why is the Moon's crust thinnest on the side facing Earth?

# Topic: Clementine and Lunar Prospector Missions Visit gpescience.com for Web links to information about the missions of the Clementine and Lunar Prospector spacecraft. Activity Make a table that lists the major goals of each mission and whether or not it succeeded.

# **The Moon's Interior**

The presence of maria on the Moon's surface tells us something about its interior. If cracks did form when the large depressions were produced by impacts, and lava did flow onto the lunar surface, then the interior of the Moon just below its surface must have been molten at that time. It is believed that this was the case and that before the Moon cooled to what it is like today, its interior separated into layers.

Other information about the Moon's interior comes from

seismographs left on the Moon by *Apollo* astronauts. Just as the study of earthquakes allows scientists to map Earth's interior, the study of moonquakes helps them study the Moon's interior and has led to the model shown in **Figure 17.** This model shows that the Moon's crust is about 60 km thick on the side facing Earth and about 150 km thick on the side facing away. Below the crust, a solid mantle may extend to a depth of 1,000 km. A partly molten zone of the mantle extends farther down. Below this is an iron-rich, solid core.



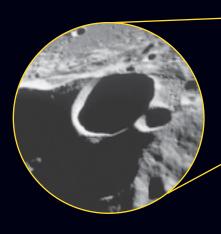
# **Exploring the Moon**

More than 20 years after the *Apollo* program ended, the *Clementine* spacecraft was placed in lunar orbit. *Clementine* compiled a detailed map of the Moon's surface, including the South Pole-Aitken Basin. This is the oldest identifiable impact feature on the Moon's surface. It is also the largest and deepest impact basin or depression found so far anywhere in the solar system, measuring 12 km in depth and 2,500 km in diameter. Because the angle of sunlight is always low near the poles, much of this depression remains in shadow throughout the Moon's rotation. This location provides a cold area where ice deposits from impacting comets may have collected. The *Clementine* spacecraft, and later the *Lunar Prospector*, both collected evidence that supports the hypothesis that water-ice has accumulated in South Pole-Aitken Basin. See **Figure 18** to learn more about this.

# NATIONAL GEOGRAPHIC VISUALIZING WATER ON THE MOON

# Figure 18

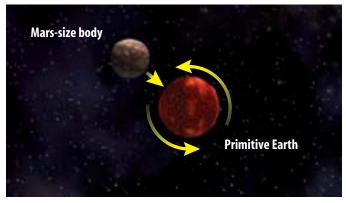
stronomers long believed that the Moon was a cold, dry place without atmosphere. But a few scientists hypothesized that water could exist on the Moon under certain conditions. This hypothesis was proven correct in the late 1990s by data from the spacecrafts *Clementine* and *Lunar Prospector*.



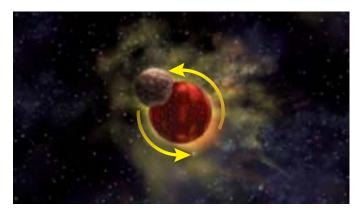
HOW DID IT GET THERE? Throughout its history, the Moon has been bombarded by comets and meteorites, most of which contain water-ice. Upon impact, some of the water would have quickly vaporized and been lost to space. However, some was deposited in the bottom of deep polar craters. Temperatures in these craters never exceed about –173°C. At these temperatures, ice could persist for billions of years.

HOW MUCH IS THERE? Estimates of how much water-ice exists vary, but some estimates are as high as 6 trillion kg. Ice might be buried several meters below the surface, either in solid blocks or as ice crystals mixed with lunar regolith. Water is important for many reasons. It would be needed for the survival of humans at any future lunar bases. Also, it could be split using solar power into hydrogen and oxygen to make rocket fuel.





A large, Mars-sized body collided with primitive Earth approximately 4.6 billion years ago.



The violent collision melted and vaporized some of Earth's crust and mantle and hurled it into space.

**Figure 19** According to the giant impact theory, the Moon formed after Earth was struck a glancing blow by a body that was more massive than Mars. For millions of years after the Moon's birth, stray rock fragments ejected by the original impact continued to pelt its surface, creating the craters that now blanket the Moon.

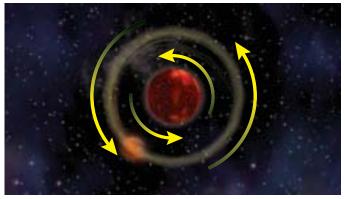
**Clementine and Lunar Prospector** Data from *Clementine* confirmed that the crust on the side facing Earth is much thinner than on the far side. Data also found that the crust thins under impact basins and showed the location of mascons, concentrations of mass that are located under impact basins. What do you think they might be? Clementine also provided information on the mineral content of Moon rocks. In fact, this part of its mission explains the spacecraft's name. Clementine was the daughter of a miner in the ballad "My Darlin' Clementine."



In 1998, the *Lunar Prospector* spacecraft orbited the Moon, taking photographs of the lunar surface. Maps made using these photographs confirmed the Clementine data. Also, data from *Lunar Prospector* confirmed that the Moon has a small, iron-rich core about 600 km in diameter. Lunar Prospector also conducted a detailed study of the Moon's surface searching for clues as to its origin and structure.

# **Origin of the Moon**

Prior to the data obtained from the Apollo space missions, there were three theories about the Moon's origin. The first was that the Moon was captured by Earth's gravity (the capture theory). It had formed elsewhere and wandered near Earth. The second theory was that the Moon condensed from the same loose material that Earth formed from during the early formation of the solar system (the binary accretion theory). The third theory was that a glob of molten material was ejected from Earth while Earth was still molten (the fission theory). Ironically, the goal of one Apollo mission was to help determine which of these theories was correct. Instead, the mission showed that none of the three theories can explain the Moon's composition.



Some material fell back to Earth, some escaped into interplanetary space, and some orbited Earth as a ring of hot gas and debris.



Solid particles eventually condensed from the cooling gas and the Moon began to accumulate.

**Giant Impact Theory** Data gathered by the *Apollo* missions led many scientists to form a new giant impact theory, which has gained wide acceptance among astronomers. According to this theory, the Moon formed about 4.6 billion years ago when a Marssized object collided with Earth. After colliding, the cores of the two bodies combined and settled toward the center of the larger object. Gas and other debris were thrown into orbit. Some fell back to Earth, but the remainder condensed into a large mass, forming the Moon. This sequence is shown in **Figure 19.** This theory helps to explain how the Moon and Earth are similar, yet not similar enough to have formed from the same condensing mass. If the core of the Mars-sized body was added to the core of Earth, this explains why the Moon's composition is like Earth's mantle and why the Moon has a much smaller central core than expected.

# section

# **Summary**

#### How does the Moon affect Earth?

- The Moon and the Sun affect Earth's tides.
- As the Moon revolves, different amounts of the side facing Earth are lighted by the Sun, causing the changing phases.
- The alignment of Earth, the Moon, and the Sun produces eclipses.

# The Moon's Surface and Interior

- The Moon's surface has craters, mountains, and maria.
- Maria are the dark-colored, relatively flat regions on the Moon.
- The *Clementine* and *Lunar Prospector* found evidence of water-ice on the Moon.

# **Self Check**

- 1. Compare and contrast solar and lunar eclipses.
- 2. Explain tides in Earth's oceans.

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- 3. Diagram the positions of Earth, the Moon, and the Sun during a full moon.
- 4. **Describe** how lunar maria might have formed.
- 5. Think Critically Why is it so important to future space exploration if the Moon has water-ice near its surface?

# **Applying Math**

**6. Calculate** An estimate of the amount of water frozen at the Moon's south pole is 100,000 m<sup>3</sup>. If this deposit was spread over an area measuring 160 m by 125 m, how many meters deep would the deposit be?



# Identifying the Mccn's Surface Features and APOLLO Landing Sites

# Goals

- **Identify** prominent surface features on the Moon
- **Determine** the relative ages of features on the Moon's surface.
- **Locate** the *Apollo* landing sites on the Moon.

#### **Materials**

large-scale maps or globes of the Moon individual, smaller maps of the Moon

# Real-World Problem =

When you look at a full moon in the night sky, you can see light and dark areas. When you look through binoculars or a small telescope, you can see many craters and the large, dark-colored maria. Many craters are named after great philosophers and scientists. The maria are named for what early scientists thought they saw there; for example, Oceanus Procellarum means "ocean of storms." Can you tell the difference between an old crater and one that has formed more recently? If craters are seen on a maria, which of the features is older? If one crater partially covers another, which one formed first?

# Procedure

- **1.** Obtain a large-scale map or globe of the Moon.
- 2. Familiarize yourself with some of the more prominent surface features of the Moon.



# Using Scientific Methods

- **3.** Look for examples of younger craters (those with sharp sides and peaks in the center) and examples of older craters (those whose sides are worn down or missing).
- **4.** Using a large-scale, labeled map or globe of the Moon, locate, identify, and label the following prominent surface features of the Moon and *Apollo* landing sites on a copy of the Moon's surface. (If an unlabeled Moon map is not available, draw one and illustrate and label the features listed below.)

Features on the Moon				
Maria	Craters	Mountain Ranges	Apollo Landing Sites	
Mare Crisium	Alphonsus	Alps	11-Mare Tranquillitatus	
Mare Frigoris	Aristarchus	Apennine	12-Oceanus Procellarum	
Mare Imbrium	Clavius	Caucasus	14-Fra Mauro	
Mare Serenitatis	Copernicus	Jura	15-Mt. Hadley	
Mare Tranquillitatus	Fra Mauro	Mt. Hadley	16-Descartes	
Oceanus Procellarum	Grimaldi		17-Taurus Littrow	
	Kepler			
	Plato			
	Tycho			

# Analyze Your Data

- **1. Describe** the specific lunar features you studied and what you learned from them.
- **2. Identify** one specific observation that helped you decide which of two features formed first.

# Conclude and Apply

- Infer from your study of the large-scale map or globe whether Copernicus Crater or Grimaldi Crater is older. Do the same for Fra Mauro Crater and Tycho Crater. Explain your answers.
- **2. Research** the *Apollo* missions and **explain** why there is no landing site for *Apollo 13*.



**Compare** your map of the Moon with the maps labeled by other students in your class. **Discuss** why individual maps may be labeled differently or why map illustrations might look different.

# Ops/ Accidents in SCIENCE

GREAT
DISCOVERIES
HAPPEN BY
ACCIDENT!

# Even Great Scientists Make M

"If I have been able to see further, it was only because I stood on the shoulders of giants."

-Sir Isaac Newton

# **Make Mistakes**

oday, scientists know that sometimes light behaves like a wave and at other times it behaves like a particle. However, early scientists believed it had to be one way or the other. Sir Isaac Newton, 1642–1727, believed in the particle nature of light. Based on his observations and a few erroneous assumptions, he eventually invented what is now called the Newtonian reflecting telescope.

# Where did Newton go wrong?

One erroneous assumption involved the behavior of light as it passes through matter such as glass, a property known as chromatic aberration. White light is composed of many different wavelengths that can disperse when refracted. This also happens with telescopes

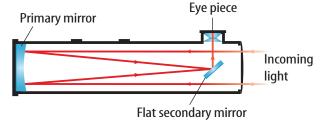
> because lenses act like a combination of many prisms and disperse white light into the colors of the rainbow. We now know that the larger the lens, the less of a prob

lem this dispersal of light causes. Newton thought the opposite was true. He tried to eliminate chromatic aberration by changing or adding lenses and using prisms, but was unable to correct the problem.

Another mistake made by Newton was that he assumed light particles begin to refract before they contact matter. Because of these assumptions, he concluded that there was no way to fix the problem. So, he gave up on refracting telescopes and used a curved mirror to focus light. This worked, because light does not disperse when it is reflected. His incorrect assumptions led to the invention of the most-used instrument in astronomy, the reflecting telescope.

Sometimes the greatest discoveries in science are based on incorrect assumptions. But, that's okay—it is called science.

#### **Newtonian Telescope**



Try it yourself Experiment with shining light through a prism and reflecting it from a mirror. Try using several different prisms with different angles.



# **Reviewing Main Ideas**

# **Section 1 Earth in Space**

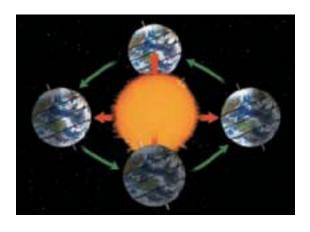
- **1.** The fact that Earth always casts a curved shadow, as shown here, is evidence of its spherical shape.
- 2. When Earth was molten, the force of gravity pulling equally in all directions caused Earth to form into a spherical shape.



- **3.** Earth's rotation and movement of matter in its core cause Earth's magnetic field.
- **4.** Earth is different than other planets. These differences enable life to flourish on Earth.

# **Section 2 Time and Seasons**

- **1.** Earth's rotation and revolution are used to measure time in days and years.
- **2.** During the year, the Sun appears to move on the ecliptic through a background of constellations called the zodiac.
- **3.** Earth experiences changing seasons because locations on Earth receive sunlight for varying amounts of time each day and at varying angles throughout the year, as shown here.



**4.** During the spring and fall equinoxes, the number of hours of day and night are nearly equal all over the world. The number of hours of daylight is greatest around the summer solstice and smallest around the winter solstice.

# Section 3 Earth's Moon

- 1. Tides in Earth's oceans are affected by the gravity of the Moon and the Sun. The Moon's gravity has a greater effect because the Moon is much closer to Earth.
- **2.** Changing positions of the Moon in relation to the Sun cause it to go through a lunar phase cycle every 29.5 days.
- **3.** Solar eclipses occur during a new moon, and lunar eclipses occur during a full moon.
- **4.** Craters, like this one, are depressions on the Moon's surface. Some large depressions may have filled with lava, forming maria.



**FOLDABLES** Use the foldable that you made at the beginning of this chapter to review the Earth-Moon-Sun system.

# **Using Vocabulary**

ecliptic p. 192 revolution p. 192
ellipse p. 188 rotation p. 192
equinox p. 195 solar eclipse p. 201
gravity p. 187 solstice p. 195
lunar eclipse p. 202 sphere p. 186
maria p. 203 tide p. 199
regolith p. 203

Match the correct vocabulary word or phrase with each definition given below.

- **1.** dark-colored, relatively flat areas on the Moon
- **2.** Earth spinning on its axis
- **3.** a large wave in Earth's oceans caused by the gravity of the Moon and the Sun
- **4.** a round, three-dimensional object, the surface of which is the same distance from the center in all directions
- **5.** Earth moving in orbit around the Sun
- 6. eclipse that occurs during a new moon
- 7. 15°-wide area on Earth's surface in which the time is the same
- **8.** occurs when Earth's axis points directly toward or away from the Sun.
- **9.** attractive force between two objects
- **10.** yearly path of Earth around the Sun

# **Checking Concepts**

Choose the word or phrase that best answers each question.

- **11.** How long is a month of lunar phases?
  - **A)** 14 days
  - **B)** 27.3 days
  - **c)** 29.5 days
  - **D)** 365 days

- **12.** In the northern hemisphere, when does Earth's rotation axis point directly toward the Sun?
  - A) summer solstice
  - **B)** winter solstice
  - **c)** fall equinox
  - **D)** spring equinox
- 13. Which movement causes lunar phases?
  - **A)** Earth's revolution
  - B) Earth's rotation
  - **C)** the Moon's revolution
  - **D)** the Moon's rotation
- **14.** Which eclipse do you experience if you are standing in the Moon's umbra?
  - **A)** partial lunar
- **c)** total lunar
- **B)** partial solar
- **D)** total solar
- **15.** Which phase occurs when the Moon is on the opposite side of Earth from the Sun?











- **16.** Which material may have been found on the Moon by the *Clementine* spacecraft?
  - A) atmosphere
  - **B)** dark-colored rocks
  - c) light-colored rocks
  - **D)** water-ice
- **17.** On average, how many degrees of longitude are contained in one time zone?
  - **A)** 0.5°
- **c)** 23.5°
- **B)** 15°
- **D)** 30°
- **18.** Which occurs a few days after a full moon?
  - A) waning crescent
  - B) waxing crescent
  - **c)** waning gibbous
  - **D)** waxing gibbous

- **19.** Which season begins around December 21 in Australia?
  - A) spring
- c) fall
- B) summer
- **D)** winter
- **20.** Which forms when small meteorites crash into the Moon?
  - A) craters
- **C)** mountains
- **B)** maria
- D) cracks

# **Interpreting Graphics**

**21.** Make an illustration showing how magnetic force lines surrounding Earth are similar to those surrounding a bar magnet.

Use the data in the table below to answer question 22.

Earth's Physical Properties		
Diameter (pole to pole)	12,714 km	
Diameter (through equator)	12,756 km	
Circumference (poles)	40,008 km	
Circumference (equator)	40,075 km	
Average distance to the Sun	149,600,000 km	
Average distance to the Moon	384,400 km	

**22.** What is the difference between the diameter of Earth through the poles compared to the equator? How many times farther from Earth is the Sun, compared to the Moon?

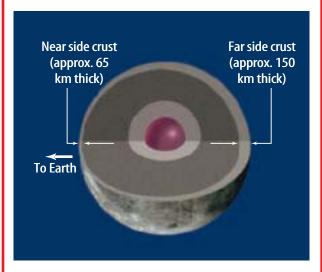
# **Thinking Critically**

- 23. Infer why more craters are present on the Moon's surface than on Earth's. Hint: Consider gravity and the presence of an atmosphere.
- **24.** Infer how seasons would be affected if Earth had no tilt instead of the 23.5° tilt that it has.

- 25. Explain why a lunar base would best be built on a plateau that is always in sunlight.
- **26.** Form a hypothesis about why during crescent phases we can often see a dim image of the rest of that side of the Moon. *Hint:* Recall the arrangement of Earth, the Moon, and the Sun during crescent phases.
- **27.** Form a hypothesis about how the thickness of the Moon's crust might play a part in the fact that the side of the Moon facing Earth has more maria than the side facing away.

# **Applying Math**

Use the illustration below to answer questions 28-29.



- **28.** Model to Scale If you are making a scale model of the Moon (diameter approx. 3,500 km), what scale should you use to obtain a model that is about 35 cm in diameter?
- **29. Calculate** Using your scale, what would the thicknesses be, in centimeters, for the near-side crust and the far-side crust?

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

# **Multiple Choice**

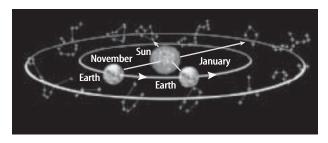
# Use the illustration below to answer question 1.



- **1.** Which theory explaining the Moon's origin is widely accepted by astronomers?
  - **A.** binary accretion theory
  - **B.** capture theory
  - **c.** fission theory
  - **D.** giant impact theory
- **2.** How far is Earth's magnetic axis tilted from its geographic axis?
  - **A.** 5°
  - **B.** 11.5°
  - **C.** 15°
  - **D.** 23.5°
- **3.** On which number did the Babylonians base their counting methods?
  - **A.** 10
  - **B.** 60
  - **c.** 100
  - **D.** 360

- **4.** Which is a way that Venus and Earth are similar?
  - A. atmospheric density
  - B. liquid water oceans
  - **c.** rocky nature
  - **D.** surface temperature

# Use the illustration below to answer question 5.



- **5.** Which is a group of constellations through which the Sun appears to move?
  - A. ecliptic
  - **B.** equinox
  - **C.** solstice
  - **D.** zodiac
- **6.** Which contains bands of charged particles known as the Van Allen belts?
  - **A.** exosphere
  - **B.** ionosphere
  - **c.** magnetosphere
  - **D.** stratosphere

# Test-Taking Tip

Caution Read each question carefully for full understanding.

- **7.** During which month of the year is Earth farthest from the Sun?
  - **A.** January
  - **B.** April
  - **C.** July
  - **D.** September

# **Gridded Response**

**8.** If a synodic month is 29.5 days long and a sidereal month is 27.3 days long, how much longer is a synodic month?

Use the illustration below to answer question 9.



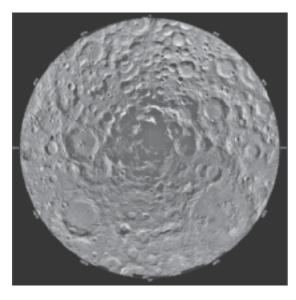
- **9.** If it is 9:00 A.M. in New York City, what time is it in San Francisco?
- **10.** If the collision of two planetary-sized objects (Earth and another object) formed the Moon, why is the Moon's iron core so small compared to Earth's?

# Short Response

- **11.** What may have caused the great difference in the percentage of CO<sub>2</sub> found in Earth's atmosphere compared to those of Venus and Mars?
- **12.** What causes the auroras?

# **Extended Response**

Use the illustration below to answer question 13.



- **13. PART A** The *Lunar Prospector* discovered possible concentrations of waterice in the area of the South Pole-Aitken Basin on the Moon. How does location and geographic terrain affect the possibility of finding water there?
  - **PART B** How might this discovery affect the future of spaceflight?

# chapter



# BIG (Idea

Gravitational forces formed the solar system and cause the planets to orbit the Sun.

# 8.1 Planet Motion

MAIN (Idea All objects that orbit the Sun move in elliptical orbits.

# **8.2** The Inner Planets

MAIN (Idea The inner planets are made mainly of rock with iron cores.

# 8.3 The Outer Planets

MAIN (Idea The outer planets are made mainly of light elements and simple compounds.

# 8.4 Life in the Solar System

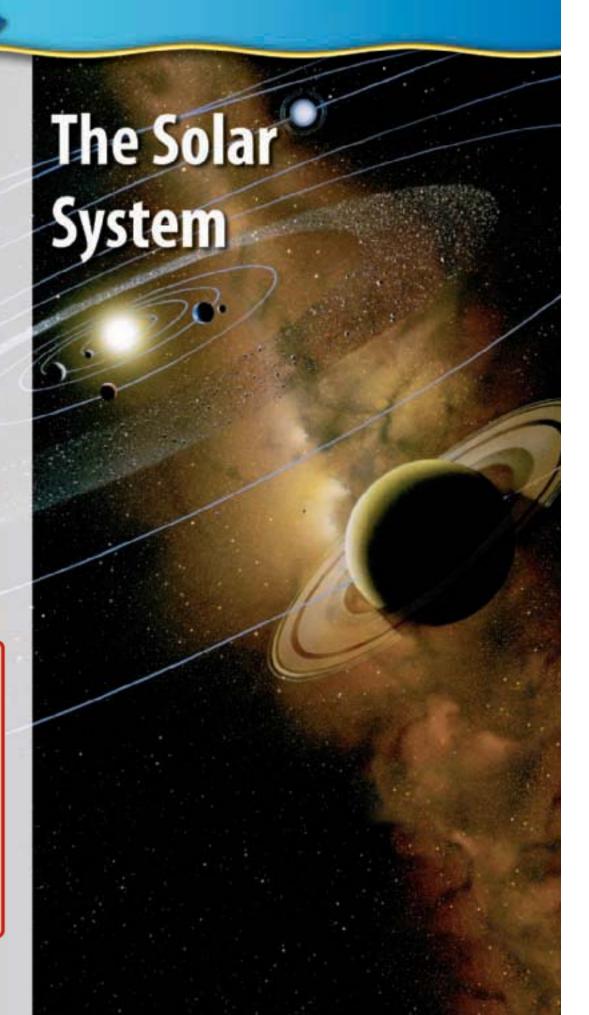
MAIN (Idea Conditions on Mars and the moons Europa and Titan might have supported life.

# Home Sweet Home

The Sun is an average star in the Milky Way galaxy, which contains billions of stars. Just as Earth and many other objects orbit the Sun, over 240 planets have been discovered orbiting other stars in the Milky Way galaxy.

# **Science Journal**

In your Science Journal, write a hypothesis about whether life might exist beyond Earth and how you would test for it.



# **Start-Up Activities**



# The Size of the Solar System

Even if you consider only the planets, the solar system is enormous compared to things you see in your daily life. You may be better able to understand the size of the solar system by using a scale model. Distances between the orbits of the planets usually are measured in astronomical units (AUs). One AU equals 150 million km, the average distance between Earth and the Sun. Using a scale of 1 AU = 10 cm and the data from the table below, draw a model of the solar system.

Planet	Distance to Sun (AU)	
Mercury	0.39	
Venus	0.72	
Earth	1.00	
Mars	1.52	
Jupiter	5.20	
Saturn	9.54	
Uranus	19.19	
Neptune	30.07	

- 1. Obtain a roll of adding-machine tape at least 4 m long. Place a symbol for the Sun on one end of the tape.
- 2. Using the scale above, measure and place the name of each planet at its proper distance from the Sun.
- 3. Think Critically In your Science Journal, explain how a scale model helped you to visualize the size of the solar system.



The Solar System Make the following Foldable to help you organize information about the planets.

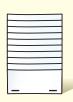
STEP 1 Collect five sheets of paper and layer them about  $\frac{1}{2}$  inch apart vertically. Keep the edge level.



Fold up the bottom edges of the paper to form ten equal tabs.



step 3 Fold the papers and crease well to hold the tabs in place. Staple along the fold. Label each tab with the names of the planets.



**Organize** As you read the chapter, write information about each planet on its sheet.



Preview this chapter's content and activities at gpescience.com

# Planet Motion

# **Reading Guide**

# What You'll Learn

- Compare and contrast geocentric and heliocentric models of the solar system.
- **Describe** each planet's position in orbit around the Sun.
- Classify planets by location and characteristics.

# Why It's Important

Understanding the solar system helps you understand Earth's position in space.

# Review Vocabulary

ellipse: an oblong, closed curve drawn around two foci

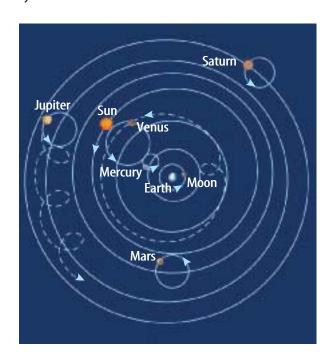
# **New Vocabulary**

- geocentric model
- heliocentric model
- astronomical unit
- extrasolar planet

# **Models of the Solar System**

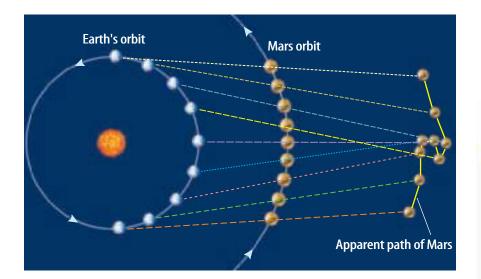
Think how difficult it would be to construct a model of the solar system if you didn't know that Earth is a rotating planet. All you can see is the nightly movement of planets across the sky and they all appear to move in a path around Earth. You can understand why many early scientists thought that Earth was the center around which everything they saw in the sky revolved.

Figure 1 Ptolemy presented his geocentric model of the solar system in 140 A.D.



Geocentric Model In the geocentric model of the solar

system, Earth is considered the center and everything else revolves around it. You have seen why ancient scientists thought this. Many early Greek scientists explained this by saying that the planets, the Sun, and the Moon were embedded in separate crystal spheres that rotated around Earth. They thought that the stars were imbedded in another sphere that also rotated around Earth. The sphere bearing the stars moved in a regular, predictable way, but those bearing the planets seemed often to move erratically against this background. For this reason, they were called planasthai, a Greek word that means "to wander." Our word planet comes from this. These ideas led to the model of the solar system devised by Ptolemy, shown in Figure 1.



**Geocentric Modifications** Although Ptolemy's model of the solar system was accepted and used for centuries, there were many problems with it. One problem was the fact that planets periodically appear to move in a retrograde, or backward, direction when viewed against a background of stars, as shown in Figure 2. The model had to be modified, and eventually it became very complex.

Heliocentric Model In spite of its complexity, the Earthcentered model was used for centuries. However, in 1543 Polish astronomer Nicholas Copernicus proposed a different model. Using an idea proposed by an early Greek scholar, Copernicus stated that the Moon revolves around Earth, and that Earth and the other planets revolve around the Sun. In this model, the apparent motion of the planets, the stars, and the Sun is due to Earth's rotation. This is the **heliocentric model**, or Sun-centered model of the solar system, shown in **Figure 3**.

**Galileo** Using his telescope, Italian astronomer Galileo Galilei found evidence that supported the ideas of Copernicus. He observed that Venus went through phases like the Moon's. These phases could be explained only if Venus orbited the Sun and passed between Earth and the Sun on each orbit. He also saw moons in orbit around Jupiter. These observations convinced him that everything didn't move around Earth. He concluded that Earth and Venus revolve around the Sun and that the Sun is the center of the solar system.

**Figure 3** In the heliocentric model of the solar system, Earth and the other planets revolve around the Sun.

**Figure 2** As Earth catches up and passes Mars, Mars appears to move backward, or retrograde.



# **Plotting Retrograde** Motion

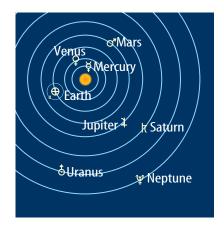
# Procedure Tow



- 1. Using graph paper, draw and label the following: *x*-axis, Right ascension, from 12 hours to ten hours; y-axis, Declination, from 0° to 20°.
- 2. Plot and label these positions of Jupiter: Oct. 1, 2003 (10h 38m, 10°); Jan. 1, 2004 (11h 21m, 6°); April 1, 2004 (10h 51m, 9°); May 1, 2004 (10h 44m, 9°); Aug. 1, 2004 (11h 20m, 6°).
- 3. Connect the plotted positions in chronological order with a solid line.

# **Analysis**

- 1. What do you notice about Jupiter's direction of motion?
- **2.** Using a heliocentric model of the solar system, explain why Jupiter appears to move as it does.





Planet Motion Johannes Kepler devised a system of equations that determine a planet's motion based on its position in the solar system. Use this equation to calculate the orbital period (in years) for Jupiter, which is 5.2 AU from the Sun.

(planet's distance in AUs)<sup>3</sup> =  $(planet's period in years)^2$ 

Check your result against the known value.

# **Understanding the Solar System**

The heliocentric model of the solar system is now known to be true. Earth and the other planets revolve around the Sun. The apparent movement of the planets and stars in the night sky is due to Earth rotating as it moves around the Sun.

In the early 1600s, the astronomer Johannes Kepler found that the planets move around the Sun in ellipses rather than circles. Kepler also found that the planets move with different speeds as they orbit the Sun. The closer a planet is to the Sun, the faster it moves. As a result, the outer planets take longer to complete one orbit than the inner planets. For example, Mercury takes just 88 days to complete one orbit, while Neptune takes 164 years.

To measure the large distances within the solar system, astronomers use a different unit. This is the astronomical unit (AU), which equals the average distance from Earth to the Sun, about 150 million km.

# **Applying Math**

# **Use Geometry**

**HELIOCENTRIC LONGITUDE (H.L.)** This is the position of a planet on any day of any year. It is plotted by measuring the angle between a line of the spring equinox in the northern hemisphere and the position of the planet on its orbit. This measurement is done counterclockwise because that is how planets appear to move when viewed from above the north pole of Earth. Plot the heliocentric longitudes given below.

**IDENTIFY** known values and the unknown value

#### **Identify known values:**

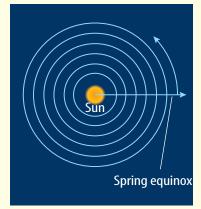
H.L. on March 4, 2004 for Mercury, Venus, Earth, Mars, and Jupiter are 344°, 103°, 164°, 84°, and 164° respectively.

#### **Identify unknown values:**

the position of each planet marked below

## SOLVE the problem

Using this diagram as a model, make a larger drawing on a piece of paper. Use a protractor to measure the H.L. angles and mark the position of each planet on its orbit in the diagram and label it with its name or planet symbol: Mercury ♥, Venus ♥, Earth ⊕, Mars ♂, and Jupiter ¼



CHECK the answers

Switch papers with another student and use a protractor to check each other's plots.

# **Practice Problems**

For more practice problems, go to p. 879 and visit Math Practice at gpescience.com.

**Classifying Planets** The planets can be classified in several ways. One system uses size and other characteristics. Those similar to Earth are called terrestrial planets. Terrestrial is from the Latin word *terra*, which mean Earth. The giant planets are called jovian planets, which comes from Jove, the English name for Jupiter.

Two other systems classify planets by location. The system used most often classifies planets whose orbits are between the Sun and the asteroid belt as inner planets and those beyond the asteroid belt as outer planets. The other system classifies planets whose orbits are between Earth's orbit and the Sun as inferior planets, and those whose orbits are beyond Earth's orbit as superior planets.



What separates the inner planets from the outer planets?

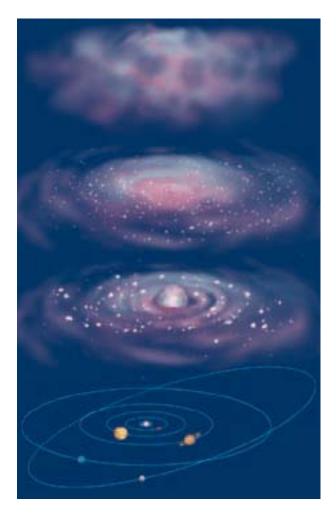
**Origin of the Solar System** Evidence suggests that the solar system probably formed as part of a group of stars. This group formed from a huge cloud of dust and gas that might have been over a million billion kilometers in diameter. More than 4.6 billion years ago, a nearby disturbance occurred, possi-

bly a shock wave from a nearby exploding star. This disturbance caused different regions of the cloud to begin to contract. One of these regions of contracting dust and gas eventually became the solar system.

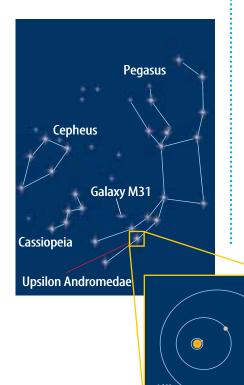
The cloud region from which the solar system formed might have been about 10 billion kilometers in diameter and was slowly rotating in space. As it continued to contract, the matter in the cloud became more dense. As its density increased, gravity pulled more dust and gas toward the center of the cloud. This caused the cloud to contract even more and become denser. At the same time, it rotated faster. As a result, the cloud flattened into a disk with a dense center, as shown in **Figure 4.** 

Temperature inside the cloud fragment increased. When it reached about ten million degrees Celsius, hydrogen fused into helium, and the Sun was born. Viewed from above the north pole of the Sun, the nebular disk rotated in a counterclockwise direction. Leftover mass in the outer portions of the disk condensed and formed planets and other objects that continue to revolve around the Sun in a counterclockwise direction.

**Figure 4** Our solar system formed from one region of a giant nebula as it contracted and became more dense.



**Figure 5** The planetary system around Upsilon Andromedae is shown below. This star is barely visible to the unaided eye.



# **Other Solar Systems**

Until recently, our solar system was the only one known. Now we know that many other stars also have planets around them. **Figure 5** shows the orbits of three planets around the star Upsilon Andromedae, a yellow star about 44 light-years away. These extrasolar planets—planets in orbit around other stars are helping astronomers learn how planetary systems form.

Astronomers have devised new techniques and instruments to find planets around other stars. So far, they have found over 200 stars that have planetary systems. Many more probably exist. Some of these planetary systems have been found around stars like the Sun, but so far only giant planets similar to Jupiter have been detected. If these large planets exist, it is possible that planets of lower mass exist also.

New instruments developed by NASA will look for Earthlike planets around other stars. It is difficult because the low mass of

> planets like Earth make them harder to find than giant planets. Even so, some of the planets found so far are comparatively low in mass and a few of these have a mass very similar to Neptune's. Scientists hypothesize this indicates that many more planets of even lower mass will be found.



Reading Check What is an extrasolar planet?

section

# Summary

# **Models of the Solar System**

- Geocentric models of the solar system place Earth in the center.
- Heliocentric models of the solar system place the Sun in the center.

# **Understanding the Solar System**

- Planet orbits are ellipses.
- Planets are classified by their positions in the solar system and by their characteristics.
- Planets move around the Sun in a counterclockwise direction.

#### **Other Solar Systems**

 Extrasolar planetary systems have been discovered.

# **Self Check**

- 1. Compare and contrast the geocentric and heliocentric models of the solar system.
- 2. Explain how heliocentric longitude is used to show the position of planets in orbit around the Sun.
- 3. Classify planets two ways using their positions in the solar system.
- 4. **Define** terrestrial planets.

review

5. Think Critically Would a year on Venus be longer or shorter than an Earth year? Explain.

### **Applying Math**

6. Using Equations Use the equation (planet's period in years) $^2$  = (planet's distance in AUs) $^3$  to find the orbital period of a planet that is 19.2 AU from the Sun.

# **The Inner Planets**

# **Reading Guide**

# *What* You'll Learn

- Compare and contrast other inner planets with Earth.
- Describe important characteristics for each inner planet.
- Evaluate the success of various missions to Mars.

# Why It's Important

Answering questions about life on other planets helps you better appreciate the unique qualities of Earth.

# Review Vocabulary

robot lander: part of a spacecraft that lands on another planet or other object

# **New Vocabulary**

- Mercurv
- Earth
- Venus
- Mars

# **Planets Near the Sun**

Recall that the solar system formed from a collapsing cloud of dust and gas. The disk that formed around the Sun contained gas and dust particles that collided with each other and clumped together. As time went on, these clumps became large enough to attract other clumps. Gradually, larger objects formed that became the planets and other objects in the solar system. Close to the young Sun, temperatures are high enough to prevent gases in the disk from condensing. As a result, planets close to the Sun are made of heavier materials, such as iron and silicates. These inner planets tend to have iron cores surrounded by rock.

# **Mercury**

The smallest and closest planet to the Sun is **Mercury**. *Mariner* 10 was the first American space probe sent to Mercury. During 1974 and 1975, it flew by the planet and sent pictures back to Earth. However only 45 percent of Mercury's surface was photographed. What we can see of its surface looks very much like our Moon's. Mercury is covered by craters, some of which have double rings, as shown in **Figure 6.** Scientists do not yet understand why this is true.

The magnetic field around Mercury, discovered by Mariner 10, indicates that Mercury has a much larger iron core than would be expected and is missing some lighter materials you would expect to find in its mantle. One theory is that two similarly sized bodies collided. Their cores merged to form one large iron core, and some of the lighter material vaporized and was lost to space.

**Figure 6** The outer ring of this double-ringed crater on Mercury is 170 km across.





**Figure 7** Thick clouds obscure the surface of Venus. This view of the surface was assembled from radar data of *Magellan* and *Pioneer Venus Orbiter* and then colorized.

Figure 8 Radar images of volca-

noes with visible lava flows on

Venus were captured by the

Magellan space probe.

**Mercury's Surface** Mercury's relatively large core and thin outer layers resulted in some extreme differences in its surface terrain. Mercury's large, solid core shrank much more rapidly than its thin outer layers. As the outer layers adjusted, they wrinkled, forming dramatic cliffs as high as 3 km. This is similar to what happens when an apple dries and shrivels up.

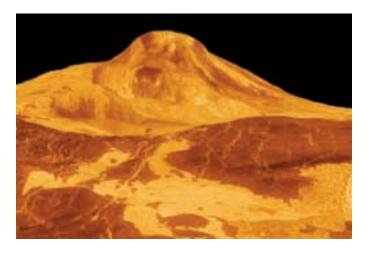
**Is there an atmosphere around Mercury?** Mercury is small and has a relatively weak gravitational pull. Its surface experiences extremes in temperature. These conditions indicate that the planet has no atmosphere. *Mariner 10* and Earth-based observations did find traces of what was thought to be an atmosphere. But these turned out to be gases that remain for a while and then leak into space. They are thought to be hydrogen and helium deposited by the solar wind and sodium and potassium vapors that diffuse upward through the crust. Mercury has no true atmosphere. This, along with its closeness to the Sun, causes surface temperatures that vary from 427°C to –170°C.

# **Venus**

Venus, shown in **Figure 7**, is the second planet from the Sun. Venus and Earth are similar in some respects; their sizes and masses are almost the same. However, one major difference is that the entire surface of Venus is blanketed by a dense atmosphere. The atmosphere of Venus, which has 92 times the surface pressure of Earth's at sea level, is mostly carbon dioxide. The clouds in the atmosphere also contain droplets of sulfuric acid, which gives them a slightly yellow color.

Clouds on Venus are so dense that only about two percent of sunlight reaches the planet's surface. However, the solar energy that penetrates warms Venus's surface. Heat radiated from Venus's surface is absorbed by the carbon dioxide gas, causing what is called a greenhouse effect. Due to this intense greenhouse

effect, temperatures on the surface of Venus are between 450°C and 475°C.





Why is Venus's surface temperature so high?

In the 1970s, the former Soviet Union sent the *Venera* lander probes to Venus. One photographed and mapped the surface before landing, but after about an hour, was destroyed by the intense heat. In 1995, the U. S. *Magellan* probe sent back radar images that revealed features of Venus, as shown in **Figure 8.** 

# **Earth**

The third planet from the Sun is **Earth**, shown in **Figure 9.** Unlike other planets, surface temperatures on Earth allow water to exist as a solid, a liquid, and a gas. Earth's atmosphere causes most meteors to burn up before they reach the surface. Ozone in Earth's atmosphere also protects life from the Sun's intense radiation. Life exists all over the planet. Life has been found on Earth in extreme conditions of temperature and pressure in which scientists would never have thought it could survive. These finds are encouraging for the possibility of life existing elsewhere in the solar system. You will learn more about this in Section 4.



**Figure 9** Seen from space, Earth's white clouds and blue oceans are evidence of the abundant water that makes life possible.

# **Figure 10** The dark region below Mars's polar cap in this *Hubble* photograph is composed of pulverized volcanic rock. A swirling storm of water-ice is visible to the

left of the polar cap.

# Mars

The fourth planet from the Sun, Mars, is called the red planet because iron oxide in some of the weathered rocks on its surface gives it a reddish color, as shown in **Figure 10.** Other Martian features visible from Earth are the polar ice caps and changes in the coloring of Mars's surface.

Mars is tilted 25° on its axis, which is very close to Earth's tilt. Because of this, Mars goes through seasons as it orbits the Sun, just like Earth does. The polar ice caps, which are made of frozen carbon dioxide and frozen water, get larger during the Martian winter and shrink during the summer. The color of Mars's surface changes according to its seasons.

In fact, both the changing sizes of the ice caps and changes in Mars's surface coloration were observed from Earth long before space probes were sent to the planet. Some people saw these changes and thought that life forms such as lichens might exist on Mars. They hypothesized that these life forms grew more during the summer, making the surface look darker. We know now that what actually causes this seasonal change in coloration of the Martian surface is wind. As the seasons change during the Martian year, winds blow the dust around on the planet's surface. When the wind blows dust off one area, it may appear darker.





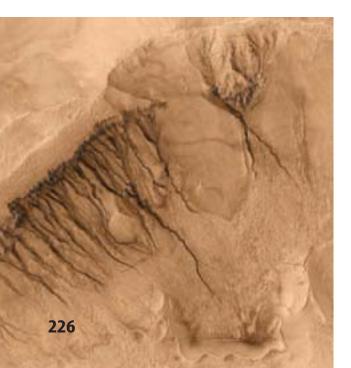
**Figure 11** These spherical concretions found on Mars provide evidence of Mar's wet past.

**Figure 12** These photographs taken by Mars Global Surveyor show gullies and channels inside the Newton Basin.

Mars's Atmosphere The Martian atmosphere is much thinner than Earth's and is composed mostly of carbon dioxide, with some nitrogen and argon. The thin atmosphere does not filter out harmful rays from the Sun as Earth's atmosphere does. Surface temperatures range from  $37^{\circ}$ C to  $-123^{\circ}$ C. This temperatures ature difference sets up strong winds on the planet, which can cause global dust storms.

Martian Moons Mars has two small, heavily cratered moons called Phobos and Deimos. Phobos is slowly spiraling inward toward Mars, and is expected to hit the Martian surface in about 50 million years. Deimos, which is smaller, orbits about 23,500 km above the surface.

**Was Mars once wet?** Currently, Mars appears to be a very dry world, but has it always been dry? The *Spirit* and *Opportunity* probes sent to Mars seem to indicate that liquid water was once on the planet and may still be there. Figure 11, a photo from Opportunity, shows round deposits on Mars that have been labeled "blueberries." These concretions are most likely composed of hematite, an iron oxide mineral. Similar concretions form on Earth in the presence of water. Figure 12 shows photographs taken in 2000 by the Mars Global Surveyor spacecraft. You can see the layering and gullies that look as if they were made by running water. Wind might have formed the layering of sediment and gullies, but more and more evidence indicates that liquid water was once present on Mars. Other formations at the edges of craters suggest that frozen water in Mars's surface may flow outward from time to time, forming the channels. A number of space probes have been sent to Mars to learn if there is, or once was, liquid water on the planet.





# **NASA on Mars**

Mars has been a priority of NASA planetary exploration for several decades. Although not all missions to Mars have been successful, several missions have returned a great amount of data. One of the earliest missions to Mars was the *Mariner 9* space probe that orbited Mars in 1971–1972. It revealed long channels on the planet that may have been carved by flowing water. *Valles Marineris* (the valley of the Mariners), shown in **Figure 13**, is a large canyon that was discovered by this early mission. It is so large that, if it were on Earth, this canyon would reach from San Francisco to New York City. It probably formed when Mars was still geologically active. *Mariner 9* also found large, extinct volcanoes. One of these, Olympus Mons, is the largest volcano found in the solar system. It is over three times higher than Mount Everest and is more than 550 km wide.

# **What is Valles Marineris?**

Until 2003, most of the information about Mars came from the Mariner 9, Viking probes, Mars Global Surveyor, Mars Pathfinder, and Odyssey. The most recent data come from the Mars Exploration Rover Mission and its two landers, Spirit and Opportunity.

**The Viking Probes** In 1976, the *Viking 1* and *Viking 2* probes landed on Mars at the locations shown in **Figure 13.** Each space-

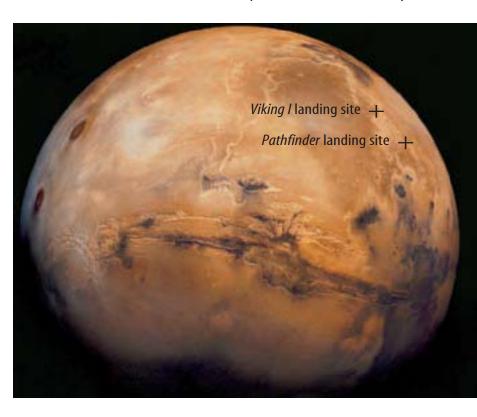
craft consisted of an orbiter and a lander. The Viking 1 and Viking 2 orbiters photographed the entire surface of Mars from orbit, while their landers conducted meteorological, chemical, and biological experiments on the planet's surface. Although initial results of the biological tests provided data that seemed to indicate the presence of life, scientists soon realized that the same data also could indicate chemical reactions. The biological experiments found no conclusive evidence of life in the soil.

The *Viking* landers also sent back pictures of Mars's reddish-colored, barren, rocky, and windswept surface.



**Activity** List new information you learned about Mars and write about the significance of each discovery in your Science Journal.

**Figure 13** Mars's *Valles Marineris* is six to seven times deeper than Earth's Grand Canyon.





Martian Minerals In addition to "blueberries," Opportunity discovered evidence that water once existed on Mars. It found deposits of salts and high concentrations of sulfur. It also found holes in Martian deposits left behind when a mineral is eroded. Research evidence that indicates water was in Meridiani Planum, Write about it in your Science Journal.

**Global Surveyor, Pathfinder, and Odyssey** Cameras on board Global Surveyor showed that the walls of Valles Marineris, shown in Figure 13, have distinct layers similar to those of the Grand Canyon. They also showed that a vast flat region, resembling a dried-up seabed or mudflat, covers a large area of Mars's northern hemisphere. Many believe the water is now frozen into Mars's crust at the poles or has soaked into the ground. In fact, a more recent probe, Mars Odyssey, provided evidence for water as frost beneath a thin layer of soil in the far northern and southern parts of Mars.

The Mars Pathfinder and its rover, Sojourner, gathered data that indicated that iron in Mar's crust may have been leached out by groundwater.

Mars Exploration Rover Mission Recall the round concretions, called "blueberries," that indicate water may once have existed on the surface of Mars. These were discovered by the Opportunity rover in Meridiani Planum. The rover confirmed that the concretions were hematite deposits. The fact that the hematite was deposited on top of other features suggests that it was deposited in a standing body of water. Other deposits of hematite have been found by the Spirit rover in Gusev Crater. The Mars Exploration Rover mission that placed these two landers on Mars provided a great deal of evidence that water existed on Mars in the past. Photographs of the Martian surface taken by the two landers Spirit and Opportunity are shown in Figure 14.



**Figure 14** The top photograph of light-colored volcanic rocks and fine-grained soils was taken by Spirit in Gusev Crater. The bottom photograph shows Opportunity's landing site on the Meridiani Planum and a rock outcrop about 8 meters away.

**Martian Meteorites** Space probes sent to Mars are not the only way we have learned about our planetary neighbor. Meteorites have been found on Earth that are believed to have been blasted into space from Mars. An interesting discovery was reported in 1996 that caused a lot of debate over the possibility of life on Mars. A meteorite from Mars (ALH84001) that had been found in the Antarctic in 1984 was studied by a group of scientists. They found long, egg-shaped microscopic structures that they thought were fossilized evidence of ancient life on Mars. The meteorite, shown in Figure 15, is thought to have been ejected by an impact on Mars about 16 million years ago.



How was a meteorite that originated on Mars found on Earth?

A debate began in which many scientists suggested other possible reasons for the egg-shaped structures. They pointed out that processes not related to life might have formed these structures. Although no firm conclusions can be drawn from this evidence, research will continue until data are found to determine whether life exists, or may once have existed, on Mars.



**Figure 15** This meteorite fragment found in Antarctica is believed to have been dislodged from Mars by a huge impact about 16 million years ago.

# section

# review

# **Summary**

### Mercury

• Mercury has an extreme range of temperatures, many craters, and long, steep cliffs.

#### **Venus**

- The sizes and masses of Venus and Earth are similar.
- The carbon dioxide in Venus's atmosphere has caused an extreme greenhouse effect, creating high surface temperatures.

- Surface temperatures on Earth allow water to exist as a solid, a liquid, and a gas.
- Earth is the only planet definitely known to support life.

#### Mars

- Mars has ice caps and surface coloring that experience seasonal changes.
- There is much evidence of water on Mars in both past and present.

# **Self Check**

- 1. Compare and contrast Mercury, Venus, Earth, and Mars.
- 2. **Describe** the atmosphere of Venus.
- 3. Explain why scientists believe Mars was once a wetter planet.
- **4. Explain** why the *Mars Exploration Rover* mission is considered a success.
- **5. Think Critically** Explain why Mars is a more likely planet for humans to visit than Venus.

# **Applying Math**

- **6. Using Percentages** If the diameter of Mars is 53.3 percent of Earth's diameter (12,756 km), find its diameter in kilometers.
- 7. Converting Units If Earth takes 365.26 days to orbit the Sun and Mars takes 686.98 days, how many Earth years does Mars take to orbit once around the Sun?



# **Interpreting Features of** Mars's Surface

Much of what scientists have learned about Mars involves interpreting data and photographs obtained from spacecraft that explored Mars. Comparing features found on the surface of Mars to similar features on Earth enables scientists to hypothesize about what may have caused these features. How can you interpret Martian surface features in the classroom?

## Real-World Problem =

How can you interpret the surface features shown on a photograph of the surface of Mars?

### Goals

- Identify surface features shown on a photograph of Mars.
- Interpret what processes were involved in the formation of these surface features.

#### Materials

photograph of the Martian surface from NASA clear-plastic sheet erasable marker scissors transparent removable tape

### Alternate Materials

additional laminated photographs of the Martian surface

## Safety Precautions 📨 🗪



## Procedure

- 1. Cut the clear-plastic sheet to fit, and tape it over the photograph.
- **2.** Use the erasable marker to mark, trace, or circle the features you can recognize, such as craters, lava flows, flow structures (channels), terraces, and sediment layering.

3. Indicate the direction that a flow of lava or water may have traveled.

# Conclude and Apply

- 1. Make a table to show the data you will obtain in this Lab.
- **2. List** in your table the features you were able to recognize in the photograph.
- **3. Identify** and **list** in your table a process that might have formed each feature.

NASA Photograph MOC2-102		
Surface Feature	Formation Process	
Do not	write	
20	book.	

- 4. Recognize cause and effect for the flow structures you identified. Record possible flow material and the direction for flow.
- **5. Infer** from which direction sunlight was shining on the Martian surface when this photograph was taken.

# ommunicating Your Data

Explain to friends, classmates, or your family that this is what NASA scientists do with data obtained from spacecraft.

# **The Outer Planets**

## **Reading Guide**

## What You'll Learn

- Compare and contrast the outer planets.
- Describe important characteristics for each outer planet.
- Evaluate the success of NASA missions Galileo and Cassini.

# Why It's Important

Studying the outer planets helps scientists to understand the formation of planets orbiting other stars.

### Review Vocabulary

space probe: an instrument that is sent to space to gather information

### **New Vocabulary**

- Jupiter
- comet
- Saturn
- asteroid
- Uranus
- meteoroid
- Neptune Pluto
- Sedna

# Why are the outer planets so different?

Compared to the inner planets, the outer planets contain large amounts of hydrogen, as well as helium, methane, and ammonia. The outer planets formed farther from the Sun, where temperatures were lower. As a result, in this region compounds such as water, methane, and ammonia formed icy coatings on dust grains. The objects formed as these grains clumped together contained large amounts of these materials. Because there was more solid material in this region, the outer planets were able to grow much larger than the planets closer to the Sun.

# **Jupiter**

The fifth planet from the Sun is **Jupiter**. Jupiter is the largest planet and contains more than twice the mass as all other planets combined. It is composed of about 90 percent hydrogen and about 10 percent helium, with very small amounts of ammonia, methane, and water vapor. Closer to the center, the atmosphere of hydrogen and helium gradually changes to a thick layer of liquid metallic hydrogen. Below this liquid layer might be a solid rocky core about the size of Earth. Temperatures in this region might be as high as 40,000°C, with pressures of 50 million Earth atmospheres.

You've probably seen pictures of Jupiter's colorful clouds. Its atmosphere has bands of white, red, tan, and brown clouds, as shown in **Figure 16.** Continuous storms of swirling, highpressure gas have been observed on Jupiter. The Great Red Spot is the most spectacular of these storms. Lightning also has been observed within Jupiter's clouds.

**Figure 16** The Great Red Spot on Jupiter in the lower right is a storm that has raged for more than 300 years.





**Figure 17** More than 60 moons orbit Jupiter. In this image, the moon Europa is to the right and the moon lo to the left.



Naming Moons You may know that the names of all the planets except Earth come from names of Greek and Roman gods. But did you realize that many of the names chosen for moons come from either mythology or literature? For example, Charon was the name of the boatman who ferried the dead to the underworld kingdom of Pluto. Research the moons of Mars and find out why their names are appropriate.

## **Space Probes to Jupiter**

In 1979, Voyager 1 and Voyager 2 flew past Jupiter, and the Galileo space probe reached Jupiter in 1995. The major discoveries of these probes include information about the composition and motion of Jupiter's atmosphere, characteristics of some of its moons (including volcanoes on one of them), and the discovery of new moons. The Voyager probes also discovered that Jupiter has faint dust rings around it.

**Jupiter's Moons** Jupiter has more than 60 moons. You can see some of them orbiting the planet in **Figure 17.** Many of these are small, rocky bodies that may be captured asteroids.

However, four are large enough to be considered small planets. Galileo was the first to discover these moons when he looked through his telescope and he drew a picture of what he saw. These Galilean moons of Jupiter are Io, Europa, Ganymede, and Callisto, and are described in more detail in **Figure 18.** One of these, Ganymede, is larger than the planet Mercury and is the largest moon in the solar system.

Io is under a constant tug-of-war between the gravities of Jupiter and Europa. This heats up the interior of Io and causes it to be the most volcanically active body in the solar system. The volcanoes on Io were first seen in photographs from the *Voyager* probes.

The most recent interpretation of the data sent back by the *Galileo* space probe about the other three Galilean moons is that they all most likely have an ocean of water underneath an icerock crust. Some scientists speculate that Europa's ocean is very large and could possibly harbor some kind of life. Using gravity and magnetic field measurements, NASA scientists generated a model that shows the existence of water beneath Europa, Ganymede, and Callisto. When *Galileo's* mission ended, NASA sent the probe into Jupiter's atmosphere, where it was crushed and destroyed. This prevented the spacecraft from crashing on Europa and contaminating any life that might exist there.



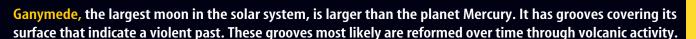
Why do scientists think Europa is a good candidate for supporting life?

## **NATIONAL** GEOGRAPHIC VISUALIZING WHAT GALILEO SAW

### Figure 18

alileo Galilei, 1564–1642 In 1610, Italian scientist Galileo Galilei did something revolutionary for his time. Galileo used a telescope to look at the planet Jupiter and saw four objects revolving around it. This and other observations convinced him that our solar system is heliocentric.

> Like its namesake, the Galileo spacecraft changed our understanding of the solar system. Galileo launched a probe into Jupiter's atmosphere, which gathered data about cloud layers, chemical composition, and lightning.



Callisto is marked by one giant crater called Valhalla, which was formed by an impact over four billion years ago. Callisto has a thin atmosphere of carbon dioxide and most likely has an ocean of salty water surrounding its interior of ice and rock.

lo is caught between Jupiter's tremendous gravitational force and the gravity of neighbor Europa. It is the most volcanically active object in the solar system.

Europa is mostly rock with a thick, cracked but smooth crust of ice.





**Figure 19** *Cassini-Huygens* provided detailed views of Saturn and its rings.



### Topic: Discoveries of Cassini-Huygens

Visit **gpescience.com** for Web links to information about discoveries made by the *Cassini* and *Huygens* probes at Saturn.

**Activity** Write a paragraph describing new discoveries made by *Cassini* space probe about Saturn.

**Figure 20** *Cassini* produced this image by measuring variations in the starlight that passes through Saturn's rings. The bright bands show where ring particles are closer together.



## Saturn

**Saturn,** shown in **Figure 19,** is the sixth planet from the Sun. It is 9.6 AU from the Sun and is about nine times larger than Earth. It is not the only planet with rings, but it has the largest and most complex ringed system. NASA began a new study of Saturn when the *Cassini-Huygens* spacecraft reached Saturn in July 2004. Since then, the *Cassini* orbiter has obtained information about Saturn, its ring system, and its moons. A number of moons have been discovered using images taken by *Cassini's* cameras. Saturn is now known to have at least 60 moons orbiting the planet.

Saturn is the second-largest planet in the solar system, but it has only about one-third as much mass as Jupiter. It has the lowest density of any planet and, in fact, is less dense than water. Like Jupiter, Saturn is composed almost entirely of hydrogen and helium, with traces of methane, ammonia, and water vapor. Saturn's interior is also similar to Jupiter's interior. Below Saturn's atmosphere is a thick layer of liquid metallic hydrogen. Saturn also might have a rocky core at its center.

**Saturn's Rings** Saturn's rings are made of billions of ice and rock particles. These particles range in size from a speck of dust to tens of meters across. Each ring particle orbits Saturn. The rings appear as several broad bands, each of which is composed of thousands of thin ringlets, as shown in **Figure 20.** Even though the ring system is over 280,000 km wide, the rings are only about 1 km thick. The rings are so thin that they seem to disappear when seen on edge. The particles in the rings are fragments produced by collisions between asteroids or comets and Saturn's moons.

The structure of the rings is caused by the gravitational interaction between the ring particles and some of Saturn's moons. These interactions cause the divisions within the rings. The gravitational forces due to some moons, called shepherd moons,

keep ring particles from spreading outward. As a result, the rings seem to have sharp edges.

Cassini-Huygens at Saturn Cassini-Huygens is actually two spacecraft in one. Cassini will orbit Saturn for over four years. It released the Huygens probe as it passed Saturn's largest moon, Titan. On January 14, 2005, Huygens descended through Titan's atmosphere and landed on its surface. It sent data back to Earth about Titan's atmosphere and surface conditions.

## **Uranus**

Uranus, shown in Figure 21, is the seventh planet from the Sun. It is about 19.2 AU from the Sun and is about four times as large as Earth. The only space probe to study Uranus was Voyager 2, which flew by the planet in January 1986.

Uranus has at least 27 moons and also has a thin ring system made of eleven separate rings. Unlike Earth and the other planets, Uranus's axis of rotation is tilted so that it is nearly parallel to the plane of the planet's orbit. The tilted rotational axis may have resulted from a collision between Uranus and another planet-sized object early in the solar system's history.

Uranus's atmosphere contains about 83 percent hydrogen, 15 percent helium, 2 percent methane, and traces of other gases. Methane in the upper atmosphere absorbs red light from the Sun, while the planet's clouds reflect blue-green light. This causes Uranus's blue-green color. Unlike Jupiter and Saturn, Uranus does not have a shell of liquid metallic hydrogen. Instead, below the atmosphere is a shell of water, methane, and ammonia, probably in liquid form. Uranus also has a small rocky core.



Reading Check What causes Uranus to have a blue-green color?

# **Neptune**

Neptune, shown in **Figure 21**, is the eighth planet from the Sun. Neptune is about the same size as Uranus and is about 30 AU from the Sun. Neptune was discovered in 1846 after studies of Uranus's orbit indicated that the orbit was being affected by gravity of another unseen planet. Voyager 2 is also the only space probe to have visited Neptune.

Neptune's atmosphere is similar to that of Uranus, but it contains about 3 percent methane. This causes Neptune to look bluer than Uranus. An internal source of planetary heat causes Neptune's atmosphere to be highly active. Wind speeds as high as 2,000 km/h have been measured on Neptune—these are the highest wind speeds measured on any planet. Below the atmosphere, Neptune is thought to have liquid water, methane, and ammonia covering a rocky core. Similar to Uranus, Neptune also has a faint ring system.

Neptune has at least 13 moons. Triton, the largest, has a diameter of 2,700 km and a thin atmosphere composed mostly of nitrogen. Some methane is also present; Voyager detected methane geysers erupting on Triton.

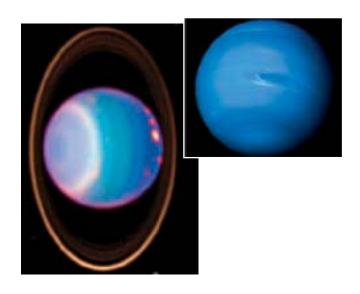


Figure 21 Uranus, left, and Neptune, right, are about the same size. Uranus has faint cloud bands and a ring system.



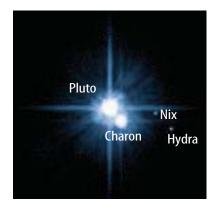
### **Comparing Sizes** of Outer and Inner **Planets**

### Procedure 7

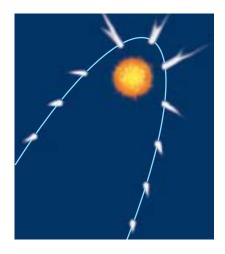
- 1. Research the planets to find their diameters in kilometers.
- 2. Select a scale to draw the planets. The scale must be such that the small planets can be seen and the larger planets can fit your paper.
- 3. Using your scale, draw a circle with the diameter of the smallest planet.
- 4. Using the same scale, draw circles representing each of the other planets.

### **Analysis**

- 1. How do the model sizes of the inner planets compare to those of the outer planets?
- 2. Which planet is smallest? Largest?



**Figure 22** Pluto's three moons are Charon, Nix, Hydra.



**Figure 23** Comets often have two tails—one made of dust and one made of ions.

**Figure 24** Asteroid 433 Eros has an irregular shape and is 23 km long. Spacecraft *NEAR-Shoemaker* landed on its surface in 2001.



## **Dwarf Planets**

In 2005, astronomers discovered an object in our solar system that was larger than Pluto. It was finally named Eris (EE rihs). Its discovery was one factor that led to a change in the definition of a planet by the International Astronomical Union (IAU) in 2006. **Pluto,** Eris, and Ceres are now known as dwarf planets.

Discovered in 1930, Pluto, has a diameter of 2,300 km, a thin atmosphere, and a surface of solid, icy rock. Pluto is about 39.2 AU from the Sun and it takes about 248 years to orbit the Sun. Pluto's three moons are shown in **Figure 22.** Eris is about 2,400 km in diameter and has one moon. Its elliptical orbit varies from 38 AU to 98 AU from the Sun. Eris orbits the Sun about once every 557 years. Ceres, discovered in 1801, has a diameter of 940 km. It is in the asteroid belt about 2.7 AU from the Sun. One Ceres year is about 4.6 Earth years.

## **Comets and Other Objects**

A **comet** is composed of dust and rock particles mixed with frozen water, methane, and ammonia. As a comet approaches the Sun, it begins to vaporize because of heat from the Sun. The released dust and gases form a bright cloud called a coma around the nucleus, the solid part of the comet. The solar wind pushes on the vaporized coma, forming a tail that always points away from the Sun, as shown in **Figure 23**.

Most comets come from a vast disk of icy comets called the Kuiper Belt near Neptune's orbit, or from the Oort Cloud that surrounds the solar system. Gravity from passing stars can disturb these areas and send comets into orbits that pass closer to the Sun. Some comets have predictable orbits, such as Halley's comet that passes near Earth every 76 years.

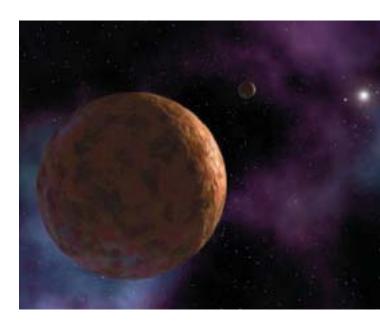
**Asteroids** Rocky objects formed from material similar to that of the planets are called **asteroids**. One of these is shown in **Figure 24.** Most asteroids are found in a belt between the orbits of Mars and Jupiter. Asteroids range in size from tiny particles to objects 940 km in diameter.

**Meteoroids** Other rocky objects orbiting within the solar system are **meteoroids**. They may have formed when asteroids collided or when comets passed close to the Sun, leaving a trail of debris. When Earth passes through these trails, meteoroids may enter the atmosphere. Most burn up completely and we see them as meteors or "shooting stars." Others do not burn completely and strike Earth. These are called meteorites.

**Sedna** Another object in the solar system that has puzzled astronomers is Sedna, shown in **Figure 25.** Sedna has been labeled a distant planetoid and with a diameter of 1,200 to 1,700 km, it is smaller than Pluto, but larger than comets in the Kuiper Belt. Also, it has a very elliptical orbit. Sedna comes as close as 76 AU from the Sun, but travels to a distance of 950 AU—far beyond the Kuiper Belt, but much closer than the Oort Cloud.

Some suggest that the Sedna's orbit was severely affected by a passing star less than 100 million years after the Sun formed. This supports the idea that our Sun formed as part of a star cluster. A close encounter with another star so soon after the Sun's formation and so nearby (800 AU) could be explained if the Sun formed within a cluster.

Another puzzle is Sedna's apparent rate of rotation of 40 days. This is best explained if the object had another object in orbit around it. Even if Sedna has no companion, there may be other similar objects, some even larger than Pluto, out there. At present, objects this far away and having orbits this elliptical can be detected only when they are closest to the Sun.



**Figure 25** This artist's conception shows what Sedna might look like as it orbits the Sun.

# section

## **Summary**

### **The Outer Planets**

- Jupiter is the largest planet in the solar system.
- The four largest moons of Jupiter are lo, Europa, Ganymede, and Callisto.
- Saturn has the most complex system of rings.
- Uranus's axis of rotation is tilted on its side.
- Neptune's atmosphere generates the strongest winds ever measured.

#### **Dwarf Planets**

- The IAU created the category called dwarf planets in 2006.
- Pluto, Eris, and Ceres are dwarf planets.

### **Comets, Asteroids, and Meteoroids**

- The asteroid belt lies between the orbits of Mars and Jupiter.
- Meteoroids form from pieces of comets and asteroids.

### Self Check

- 1. Compare and contrast Jupiter, Saturn, Uranus, Neptune, and Pluto.
- **2. Explain** what Saturn's rings are composed of.

review

- 3. List three things scientists learned about Jupiter and its moons from the Galileo space probe.
- **4. Think Critically** Explain what would happen to the density of Saturn if its atmospheric layers squeezed inward toward the center of the planet.

### **Applying Math**

- 5. Use Numbers If the diameters of Earth and Jupiter are 12,756 km and 142,984 km, respectively, how many Earths could fit across Jupiter's equator?
- 6. Use Decimals On average, if Earth is 150 million km, or 1 AU, from the Sun and Venus is 0.71 AU from the Sun, what is the distance to Venus in kilometers?



# Life in the Solar System

## **Reading Guide**

# What You'll Learn

- Evaluate other planets in the solar system for the possibility of containing life.
- **Examine** life forms that exist in exotic locations on Earth.
- Discuss locations in which life might exist on other planets.

# Why It's Important

The lack of evidence showing that life exists elsewhere helps you realize how important it is to take care of Earth.

### Review Vocabulary

**fossil:** remains, imprints, or traces of past life

### **New Vocabulary**

extraterrestrial life

## **Life As We Know It**

We know life exists in our solar system. It's all around us; in the air, on rocks, and in the sea, as shown in **Figure 26.** It thrives even in harsh environments on Earth, but does it exist anywhere else in the solar system and, if so, where? What does life need to survive? Life on Earth is carbon-based and requires water to survive. Does water exist elsewhere in sufficient quantities to make life possible?

Think about what you consider to be life. You might think of yourself, your friends, your pet, and maybe birds flying by the window. There is so much diversity to life on Earth. There is life we easily can see, such as grass, trees, and animals. There is also a multitude of life that we cannot see. For example, microorganisms are so small you need a microscope to see them. When we define life, we might forget about microorganisms but they are very important to us.

If you were asked to check a sample of soil to see if there was or ever had been life in it, what would you do? You might look for moving things, but motion doesn't always mean something is alive. You might look for residues or traces of life that once lived in the soil, such as fossils. You know that you release gases as you breathe. You might check to see if gases are being emitted from the soil. Think about what type of tests you could perform on Martian soil to check for life. Remember that these tests would have to be done by a robot lander.

**Figure 26** Tube worms and mussels at this hydrocarbon seep on the floor of the Gulf of Mexico get their energy from bacteria that consume methane. Predators, such as crabs feed on the community.



**Exotic Life on Earth** Before we rule out the possibility of life on other worlds, we should take a closer look at life on Earth. Some of the exotic life-forms that exist on Earth are strange, indeed.

In the 1970s, a research submarine, the *Alvin*, found some interesting life-forms while exploring hot, volcanic vents on the ocean floor at depths where light could not penetrate.

A variety of life was living where scientists didn't think it could. Lifeforms found included crabs, clams, and tubeworms. They were living and thriving in a dark environment under tremendous pressures. Alvin also discovered colonies of bacteria living off the extremely hot material spewing from volcanic vents. These organisms use thermal and chemical energy to survive and are the basis of food webs there.

A surprising amount of life has been found elsewhere on Earth in

extreme conditions—scalding heat, freezing cold, salt, lye, and darkness. For example, a moss shown in Figure 27 was dormant for 40,000 years in permafrost in northeastern Siberia. Three forms of bacteria thrive in the mud of Mono Lake, California, where the environment is dark, lacks oxygen, and contains a large amount of salt and lye. What does this tell us about the ability of life to exist in the harsh environments of other planets?

## Can life exist on other worlds?

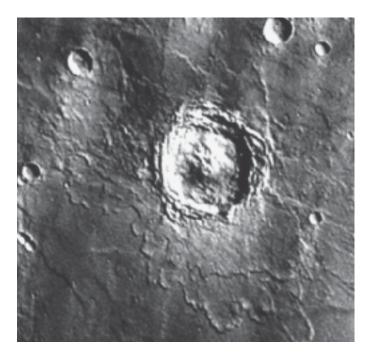
Think about what you have learned about Earth compared to other planets. None of the planets you have studied has characteristics so close to Earth's that you could definitely say life as we know it could exist there. But can you say for certain that life cannot exist on other planets in the solar system?

The high temperatures found on Mercury and Venus and the lack of a surface on Jupiter and the other gaseous giants make finding life as we know it unlikely. But such facts do not rule out the possibility of some form of extraterrestrial life, that is, life on other worlds. Let's take a look at some places where scientists are searching for extraterrestrial life.





Figure 27 The moss shown to the left is growing again after being dormant for 40,000 years. The photograph above shows a researcher collecting mud samples from Mono Lake, California. One bacteria in this mud obtains energy from chemicals rather than sunlight.



**Figure 28** This crater on Mars is called a splosh crater. It is hypothesized that a splosh crater forms from the impact of an object on a water-soaked surface.

**Figure 29** Surface cracking on Europa may indicate that a liquid ocean lies beneath.

**Mars** During most of Earth's history, onecelled organisms were the major form of life on Earth. Could such life-forms be present on Mars today or could they have existed on Mars in the past when the planet was wetter? Evidence from space probes has shown that Mars probably had large amounts of water on its surface, as shown in Figure 28. If life existed and left evidence, future astronauts will find it. Such a discovery would be almost as exciting as finding living life-forms.

Actually, searches for life on Mars already have been done. Viking landers on Mars performed some tests designed to detect life. The first tests showed positive results, but additional study showed that these results could be explained just as well by chemical

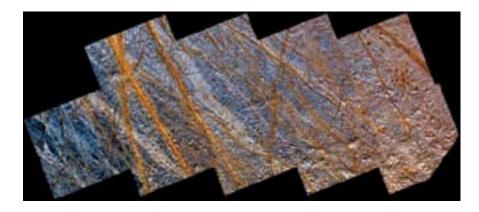
reactions that did not require life. Ultimately, the *Viking* experiments found no evidence of life. However, the tests used only would detect life similar to that which exists on Earth. What if life on Mars is totally different from life on Earth?

**Europa** Data from the *Galileo* probe of Jupiter and its moons indicate that three Galilean moons have ice-covered oceans. The oceans under the ice of Ganymede and Callisto might be partially frozen. However, data related to surface cracking, as shown in Figure 29, tidal bulges, and movement of the surface over some lubricating substance below, support the idea of a liquid ocean about 25 km deep in Europa. Europa's ocean could hold more than twice the amount of water that Earth's oceans hold.

Some scientists speculate there is a chance that Europa's ocean could harbor life. One reason is that it might be deep and long-lasting, possibly even liquid water that is warmed by Jupiter's gravitational pull on Europa.

On Earth, we find life everywhere there is water. If life can

exist in extremely hot liquid flowing from volcanic vents on Earth's ocean floor, could it not exist in a similar environment if it exists on Europa? In fact, ocean currents have been detected on Europa. Today, some scientists consider Europa to be the most promising location to look for extraterrestrial life.



**Titan** Saturn's moon, Titan, shown in **Figure 30**, is larger than Mercury and has an atmosphere composed mostly of nitrogen, with some argon and methane. Certain features on Titan's surface indicate this moon has a long-term, interesting geologic history. Some darker areas contain relatively pure water-ice, while other, brighter areas are composed of hydrocarbons, organic compounds containing hydrogen and carbon. Recall that life on Earth is carbon-based. A bright cloud of the hydrocarbon methane is visible near the south pole. Large particles in this area indicate that a dynamically active atmosphere exists there.

The presence of hydrocarbons on the surface of Titan interests exobiologists, scientists who search for evidence of life on other worlds. Also, the apparent absence of large impact craters indicates that Titan has experienced internal geologic activity. This activity could provide the energy needed for organic molecules to develop into the building blocks of life.

However, the *Huygens* probe, which landed on Titan in 2005, found that the surface at the landing area was dry. Although there was evidence for liquid having been present in the past, there seemed to be no seas of liquid hydrocarbons.



**Figure 30** This image of Titan taken by *Cassini* shows two thin layers of hazy atmosphere that are thought to contain nitrogen and methane.



What fact about Titan particularly interests exobiologists?

# section (4) review

### **Summary**

#### Life As We Know It

• Life as we know it is carbon-based and needs liquid water to survive.

#### **Exotic Life On Earth**

- Life exists in extreme environments on Earth.
- Life can remain dormant for long periods of time and still survive.

#### Mars

• *Viking's* tests for life on Mars were inconclusive.

#### **Europa**

- There is strong evidence for a warm, liquid ocean on Europa.
- Europa is considered the most promising location to look for extraterrestrial life.

#### **Titan**

Organic compounds exist on Titan.

### **Self Check**

- 1. **Define** extraterrestrial life.
- **2. Describe** how finding life in extreme environments on Earth supports the idea that life may exist elsewhere.
- **3. Explain** how hot fluids from volcanic vents on Earth's ocean floor support energy for life.
- **4. Discuss** other locations in the solar system where life may once have existed.
- **5. Think Critically** Explain why scientists consider Europa to be a good place to search for extraterrestrial life.

### **Applying Math**

- 6. Use Numbers Atmospheric pressure at the surface of Venus is 92 times Earth's at sea level. If atmospheric pressure on Earth at sea level is 101.3 kPa, find the atmospheric pressure on the surface of Venus in kPa.
- **7. Use Percentages** The average composition of Mars's atmosphere is 95% CO<sub>2</sub>, 3% N, and 2% Ar. Approximately what fraction of Mars's atmosphere is nitrogen?



# **Design Your Own**

# Testing Unknown Soil Samples for Life

### Goals

- Identify several things that you might see if life existed in an unknown sand or soil sample.
- Demonstrate processes you could use to search for life in the unknown sample.
- Illustrate evidence of life that you observe in each of your samples.
- Compare and contrast observations that may or may not indicate that life exists in your samples.

### **Possible Materials**

clear plastic cups (3) sand or soil warm tap water magnifying glass thermometer

### **Safety Precautions**



## Real-World Problem

What is life? You know that life needs water, air, and food to survive. The type of food depends on the life form. You eat certain foods to provide you with the energy to live. Other forms of life need different foods for energy. You know that many plants make their own food using photosynthesis, and you have learned about life-forms on Earth that obtain their energy from chemical reactions. How might you find out if life is present in an unknown sample? Perhaps you might look for evidence that an organism was taking in one gas and expelling others. Perhaps you might look for energy being produced. How could you determine if an unknown sample of sand or soil contained life?

# Form a Hypothesis

Form a hypothesis about what evidence might indicate that a sand or soil sample contained life. Have your teacher approve your hypothesis before you begin your experiment.

# Test Your Hypothesis

### Make a Plan

- 1. As a group, agree upon the hypothesis and decide how to test it. Identify which results will confirm your hypothesis.
- **2. List** the steps you will need to test your hypothesis. Be sure to include a control run. Describe exactly what you will do in each step.



# Using Scientific Methods

- **3. List** the materials you will need to perform the experiment. Determine who will prepare your unknown samples from your materials.
- **4. Prepare** an illustration in your Science Journal where you will record your observations.
- **5. Read** the entire experiment to make sure all steps will be performed in a logical order.
- **6. Identify** all constants, variables, and controls of the experiment. Keep in mind that the person who prepares your unknowns must follow your instructions carefully and not divulge which sample(s) contain life.

#### **Follow Your Plan**

- **1.** Make sure your teacher approves your plan and oversees the preparation of your unknown samples before you start.
- **2.** Carry out your experiment as planned.
- **3.** While doing the experiment, record your observations in your illustration in your Science Journal.



# Analyze Your Data

- **1. Illustrate** your visual observations of unknown sand or soil samples.
- **2.** Label your drawings with other observations that you make, such as production of heat or change in odor.

# Conclude and Apply

- Examine Do the illustrations show the observations you expected to make? Describe any unexpected observations noted.
- 2. **Determine** Do any of your observations indicate that life exists in any of your unknown samples? Describe any inconclusive observations.
- **3. Draw Conclusions** Did your results support your hypothesis? Explain why or why not.



**Compare** your data with those of other students. Discuss how your experiments may have differed, and how this could have changed the observations.

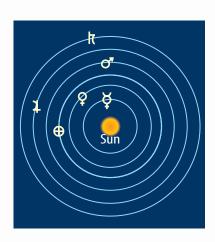
# SCIENCE Stats

# Night Sky Wonders

## Did You Know...

... Five planets can be seen from Earth without the aid of a telescope or binoculars. Mars, Venus, Mercury, Jupiter, and Saturn can be seen at various times throughout the year in the night or early morning sky. Mercury is visible for only a few days, but the other planets are often clearly visible, such as Mars and Venus shown here.





# ... All five planets were visible as a group in the evening sky in the spring of 2004.

All five planets were briefly positioned on the same side of the Sun at the same time. This stunning sight will not be seen in the evening skies again until 2036. Because they orbit the Sun at different rates, it is rare for all five visible planets to be as close together in the sky as they were in 2004.

## **Applying Math**

- 1. How old will you be when the next planetary alignment like the one that was visible in 2004 can be seen from Earth again?
- 2. The reflected light we see when observing planets travels through space at 300,000 km/s. If Jupiter is 588.5 million km from Earth at its closest approach, what is the minimum amount of time required for light to reach Earth from Jupiter?
- **3.** Using the heliocentric longitude diagram you made in the Applying Math feature, plot the positions of the planets using the following longitudes: Mercury 96°, Venus 135°, Earth 184°, Mars 94°, Jupiter 165°, and Saturn 103°.

Gordon Garradd/Photo Researchers

## **Reviewing Main Ideas**

## Section 1 Planet Motion

- 1. In the geocentric model of the solar system, Earth is in the center. In the heliocentric model, the Sun is in the center.
- 2. Planets move in elliptical orbits around the Sun and move faster the closer they are to the Sun.
- **3.** Inner planets have orbits closer to the Sun than the asteroid belt; outer planets have orbits beyond the asteroid belt.
- **4.** A large nebula, like the one shown below, fragmented into smaller ones, one of which later condensed and flattened to form the solar system.



## **Section 2** The Inner Planets

- **1.** Mercury has a larger iron core than expected for a planet its size.
- **2.** The carbon dioxide in Venus's dense atmosphere has caused a strong greenhouse effect that produces very high surface temperatures.
- **3.** Mars landers like the one shown in the next column have provided evidence that Mars, once had more water on its surface than it does today.



## **Section 3** The Outer Planets

- **1.** Jupiter is the largest planet in the solar system and has the most moons. Four of these moons were first seen by Galileo.
- **2.** Saturn has the most developed ring system of all outer planets.
- **3.** The green-blue color of Uranus and the blue color of Neptune are caused by methane in their atmospheres.
- **4.** The dwarf planets include Ceres, Pluto, and Eris. Pluto has a thin atmosphere and an icy rock surface.

## **Section 4 Life in the Solar System**

- **1.** Life exists in extreme environments on Earth and may be able to survive in extreme environments on other planets.
- **2.** Europa is considered the most promising location in the solar system to look for extraterrestrial life.

FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review details about each of the planets.

## **Using Vocabulary**

Mars p. 225 asteroid p. 236 astronomical unit p. 220 Mercury p. 223 comet p.236 meteoroid p. 236 Earth p. 225 Neptune p. 235 Pluto p. 236 extrasolar planet p. 222 extraterrestrial life p. 239 Saturn p. 234 geocentric model p. 218 Sedna p. 237 heliocentric model p. 219 Uranus p. 235 Jupiter p. 231 Venus p. 224

Use what you know about the vocabulary terms to explain the differences in the following sets of words. Then explain how they are related.

- 1. Uranus—Neptune
- 2. extrasolar planet—extraterrestrial life
- 3. Pluto—Sedna
- 4. Venus—Earth
- **5.** Mercury—Jupiter
- 6. asteroid—Sedna
- **7.** geocentric model—heliocentric model
- 8. astronomical unit—Earth
- 9. Jupiter—Saturn
- 10. Earth—Mars

## **Checking Concepts**

Choose the word or phrase that best answers the question.

- **11.** Who proposed the heliocentric model of the solar system?
  - A) Copernicus
- **c)** Kepler
- **B)** Galileo
- **D)** Ptolemy
- **12.** Which planet has the most complex ring system?
  - **A)** Jupiter
- **C)** Saturn
- **B)** Neptune
- **D)** Uranus

- **13.** Which planet is the red planet?
  - **A)** Jupiter
- **C)** Neptune
- **B)** Mars
- **D)** Venus
- **14.** Which chemical or gas produces a greenblue to blue color in Uranus and Neptune?
  - **A)** carbon dioxide
- **c)** oxygen
- **B)** methane
- **D)** sulfur dioxide
- **15.** Which planet has the highest surface temperature?
  - A) Earth
- **C)** Mercury
- **B)** Mars
- **D)** Venus
- **16.** Which fact is true of superior planets?
  - **A)** Earth-sized
  - **B)** Jupiter-sized
  - **c)** lie beyond Earth's orbit
  - **D)** lie beyond the asteroid belt
- **17.** Which Galilean satellite has active volcanoes?
  - **A)** Callisto
- **c)** Ganymede
- **B)** Europa
- **D)** Io

Use the illustration below to answer question 18.

- **18.** Which planet is shown?
  - **A)** Jupiter
  - **B)** Mars
  - **c)** Saturn
  - **D)** Venus



- **19.** Which part of a comet is on the opposite side of a comet from the Sun?
  - A) coma
- **c)** nucleus
- **B)** head
- **D)** tail
- **20.** What is a reason Europa might be a good place to look for extraterrestrial life?
  - **A)** liquid methane
  - **B)** presence of organic molecules
  - c) rust-colored rocks
  - **D)** water ocean and tidal energy

## **Interpreting Graphics**

- **21.** Make a table summarizing the gases contained in the atmospheres of the planets.
- **22.** Make a model of how you think the geocentric model of the solar system was organized.

Use the data in the table below to answer questions 23–25.

Planet Orbits		
Planet	Distance to the Sun (AU)	
Mercury	0.39	
Venus	0.72	
Earth	1.00	
Mars	1.52	
Jupiter	5.20	
Saturn	9.54	
Uranus	19.19	
Neptune	30.07	

- **23.** Which planet is a little over nine times farther from the Sun than Earth?
- **24.** How far is the orbit of Mars from that of Jupiter in AU's?
- **25.** How much closer to Earth is Venus than is Mars?

### **Thinking Critically**

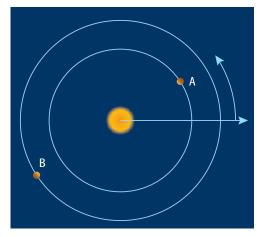
- **26. Explain** why Venus has a higher surface temperature than Mercury even though Mercury is closer to the Sun.
- **27. Form a hypothesis** about where the oxygen that combined with the iron in rocks on Mars came from.

- **28. Classify** a newly discovered planet, by using three classification systems, with the following characteristics: 10,000 km in diameter, rocky surface, an orbit beyond Pluto's.
- **29. Explain** why Mars, Europa, and Titan are of interest to scientists searching for extraterrestrial life.
- **30. Explain** several reasons why Earth is the only planet in the solar system that appears capable of supporting life as we know it.

### **Applying Math**

- **31.** Use Angles How far around in its orbit would a planet be if its heliocentric longitude was 90 degrees?
- 32. Calculate Jupiter's distance from the Sun is 5.2 AUs. Use the equation (planet's distancein AUs)<sup>3</sup> = (planet's period in years)<sup>2</sup> to calculate Jupiter's period of revolution.

Use the diagram below to answer No. 33.



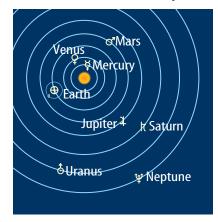
- **33. Use Angles** If the Heliocentric Longitude (H. L.) of planet A is 33 degrees, what is the approximate H.L. of planet B?
- **34.** Using Equations Use the equation  $V = \frac{4}{3} (\pi r^3)$  to determine the volume of Venus, which has a radius of 6052 km.

# chapter Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

### Multiple Choice

### Use the illustration below to answer question 1.



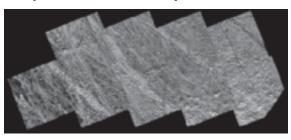
- **1.** As seen from above their north poles, in which direction do planets move around the Sun?
  - A. clockwise
  - **B.** counterclockwise
  - **C.** geocentric
  - **D.** heliocentric
- **2.** Which model of the solar system places the Sun in the center?
  - **A.** geocentric
  - **B.** heliocentric
  - **c.** inferior
  - **D.** superior

### Test-Taking Tip

**Practice** Remember that test-taking skills can improve with practice. If possible, take at least one practice test and familiarize yourself with the test format and instructions.

- **3.** What did Galileo observe about Venus?
  - **A.** It goes through phases.
  - **B.** It has two moons.
  - **c.** It is covered by clouds.
  - **D.** Its surface temperature is over 450°C.
- **4.** Who determined that planets orbit the Sun in elliptical orbits?
  - A. Brahe
  - **B.** Copernicus
  - **c.** Kepler
  - **D.** Ptolemy

### Use the photo below to answer question 5.



- **5.** Which moon of Jupiter, pictured here, is most likely to have liquid water under its ice crust?
  - A. Callisto
  - **B.** Europa
  - **c.** Ganymede
  - **D.** Io

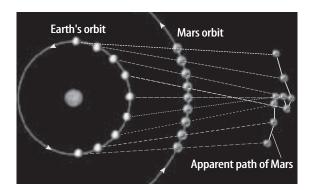
- **6.** Which is composed of dust and rock particles mixed in with frozen water, methane, and ammonia?
  - A. asteroid
  - B. comet
  - **C.** meteoroid
  - **D.** meteorite

### **Gridded Response**

- **7.** Saturn travels 360° around the Sun for 29.5 years to complete one orbit. How many years will it take Saturn to complete 195° of its orbit?
- **8.** If the orbital radius of Jupiter is 5.2 AU, what fraction of that distance is Earth's orbital radius?

## **Short Response**

Use the illustration below to answer question 9.

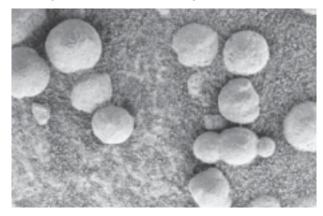


**9.** How does retrograde motion of planets, such as Mars shown in the illustration, provide support for the heliocentric model of the solar system?

- **10.** What causes Mars to have a reddishorange color?
- **11.** Why was the *Galileo* spacecraft given this name?
- **12.** What is generally true of all jovian planets?
- **13.** Compare and contrast Venus to Earth. Why does it appear unlikely that Venus is capable of supporting life as we know it?
- **14.** Compare and contrast Jupiter to Earth. Why does it appear unlikely that Jupiter is capable of supporting life as we know it?
- **15.** Why would the discovery of oceans existing under the surface ice of Europa be so interesting to astronomers?

### **Extended Response**

Use the photo below to answer question 16.

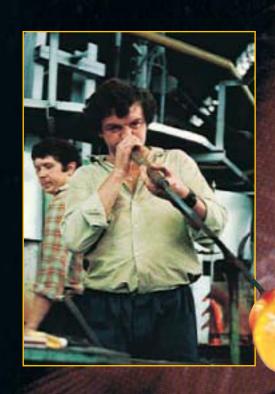


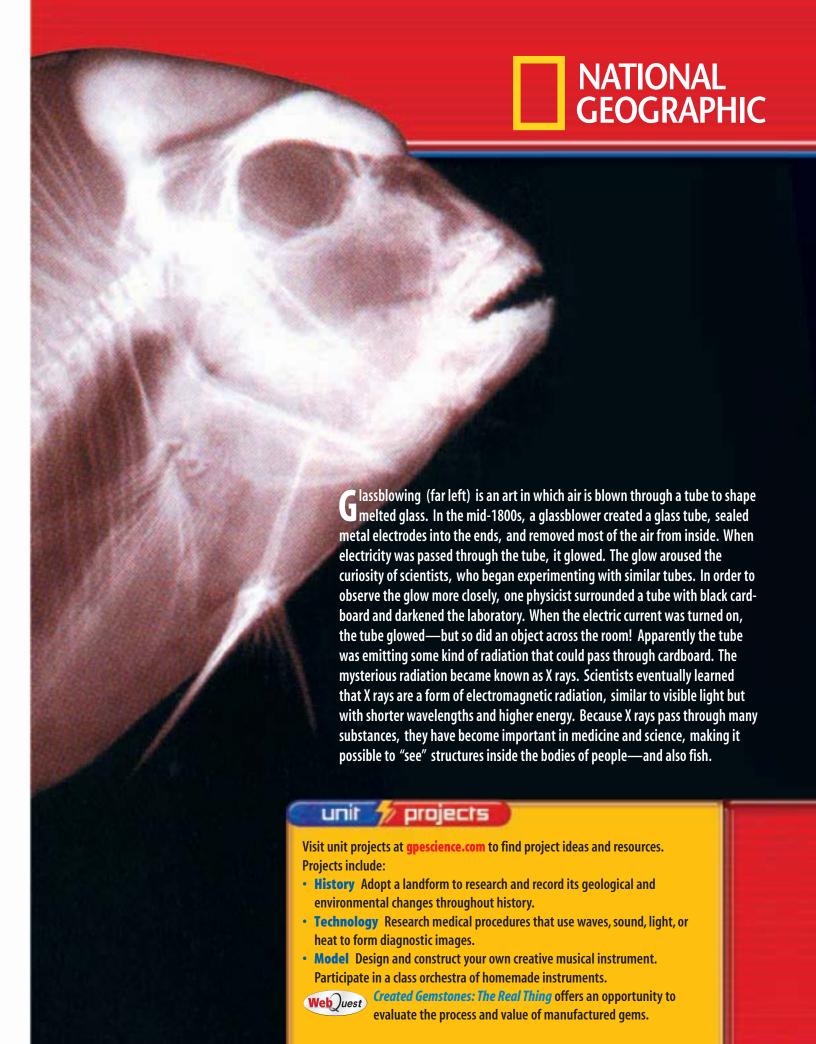
- **16. PART A** What, shown in the photograph, did the NASA spacecraft, Opportunity, discover on Mars?
  - **PART B** Why is this discovery so important?



# **Energy in Motion**

How Are Glassblowing & X Rays Connected?





# chapter



### BIG (Idea

The atoms and molecules that make up matter move in random motion.

# 9.1 Temperature and Thermal Energy

MAIN (Idea The temperature of a material depends on the average kinetic energy of the particles in a material.

### 9.2 States of Matter

MAIN (Idea Particle motion changes when matter changes from one state to another.

# 9.3 Transferring Thermal Energy

**MAIN** (Idea Thermal energy is transferred by conduction, convection, and radiation.

### 9.4 Using Thermal Energy

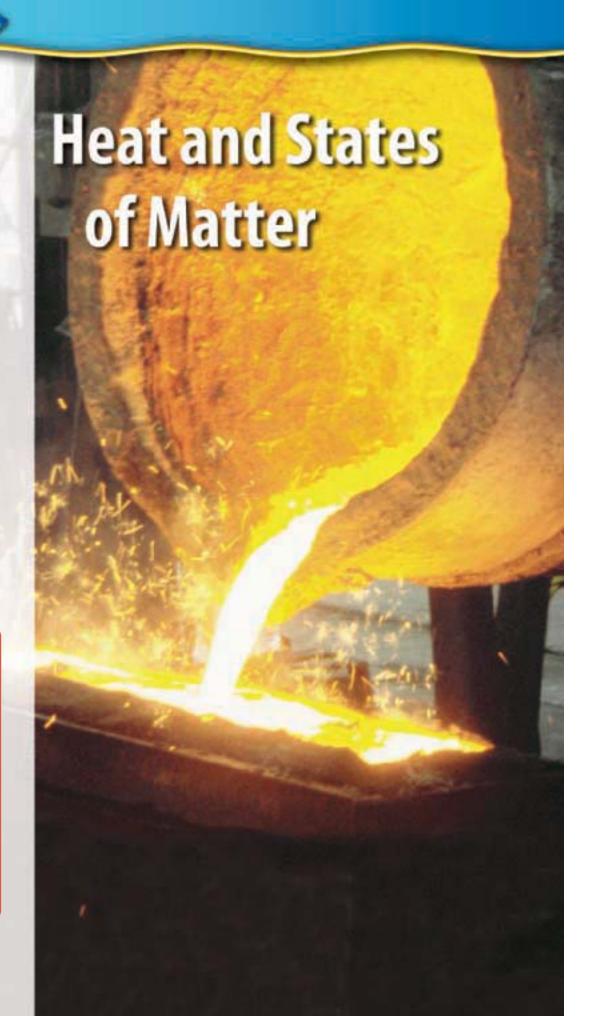
MAIN (Idea Thermal energy is made useful by controlling its production and movement.

### Hot Stuff

This hot, glowing liquid will become solid steel when it cools. The difference between liquid and solid steel is energy—thermal energy. Increasing the thermal energy of solid steel can cause it to melt and change into a fiery liquid.

### **Science Journal**

Describe things you do to make yourself feel warmer and cooler.



# **Start-Up Activities**



### **Expansion of a Gas**

Why does mercury in a thermometer rise? Why do sidewalks, streets, and bridges have cracks? Many substances expand when heated and contract when cooled, as you will see during this lab.



- 1. Blow up a balloon until it is half filled. Use a tape measure to measure the circumference of the balloon.
- 2. Pour water into a large beaker until it is half full. Place

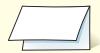
the beaker on a hot plate and wait for the water to boil.

- 3. Set the balloon on the mouth of the beaker and observe for 5 min. Be careful not to allow the balloon to touch the hot plate. Again measure the circumference of the balloon.
- **4. Think Critically** Write a paragraph in your Science Journal describing the changing size of the balloon's circumference. Infer why the balloon's circumference changed.



Thermal Energy and States of Matter Make the following Foldable to help you understand thermal energy and states of matter.





**STEP 2** Fold in half from side to side with the fold at the top.



once. Cut only the fold of the top flap to make two tabs.



Turn the paper vertically and label the front tabs as shown.



**Find Main Ideas** As you read the chapter, write the main ideas you find about thermal energy and states of matter under the appropriate tab.



Preview this chapter's content and activities at qpescience.com

# **Temperature and Thermal Energy**

## **Reading Guide**

### What You'll Learn

- Define temperature.
- Explain how thermal energy and temperature are related.
- **Calculate** the change in thermal energy of an object due to a temperature change.

## Why It's Important

Cars, buses, trucks, and airplanes could not operate without thermal energy.

## Review Vocabulary

kinetic energy: energy an object has due to its motion

### New Vocabulary

- kinetic theory
- Kelvin
- temperature
- thermal energy
- heat
- specific heat

# **Kinetic Theory of Matter**

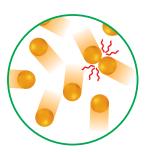
All around you objects are warming and cooling. What is temperature and what causes the temperature of an object to change? The temperature of an object is related to the motion of the particles in that object. The motion of the particles in matter is described by the **kinetic theory** of matter.

According to the kinetic theory, matter is composed of particles that are atoms, molecules, or ions that always are in random motion. This means that the particles in matter are moving at different speeds in all directions. Because these particles are in motion, they have kinetic energy. These particles also can collide and kinetic energy can be transferred from one particle to another particle.

Reading Check How do the particles in matter move?

**Figure 1** When particles collide, kinetic energy can be transferred from one particle to another and the direction of particle motion changes.







# **Temperature**

The particles in matter are moving at various speeds and have a range of kinetic energies. The **temperature** of a substance is a measure of the average kinetic energy of its particles. As the average speed of the particles in random motion increases, the temperature of the substance increases. For example, the particles in hot tea move faster on average than those in iced tea.

**Temperature Scales** The SI unit for temperature is the Kelvin (K). More commonly used temperature scales are the Celsius scale and the Fahrenheit scale. Subtracting 273 from a temperature in Kelvin converts the temperature to degrees Celsius. Temperatures measured on the Celsius and Fahrenheit scales can be converted into one another using these equations:

### **Celsius-Fahrenheit Conversion Equations**

To convert temperature in °F to °C: °C =  $\frac{5}{9}$  (°F - 32)

To convert temperature in °C to °F: °F =  $\frac{9}{5}$  °C + 32

## **Applying Math**

## **Solve a Simple Equation**

**CONVERTING TO CELSIUS** What is a temperature of 86°F on the Celsius scale?

**IDENTIFY** known values and the unknown value

Identify the known values:

the temperature is 
$$86^{\circ}F$$
  $\stackrel{\text{means}}{\longrightarrow}$   $^{\circ}F = 86$ 

Identify the unknown values:

What is this temperature on the Celsius scale?  $^{\circ}$ C = ?

SOLVE the problem

Substitute the temperature 86°F into the equation that converts °F to °C:

$$^{\circ}$$
C =  $\frac{5}{9}$  ( $^{\circ}$ F - 32) =  $\frac{5}{9}$ (54) = 30 $^{\circ}$ C

**CHECK** your answer

Does your answer seem reasonable? Multiply your answer by  $\frac{9}{5}$  and add 32. The result should be the given Fahrenheit temperature.

### **Practice Problems**

- **1.** What is  $-40^{\circ}$ F in degrees Celsius?
- **2.** What is a temperature of 22°C in degrees Fahrenheit?

For more practice problems, go to page 879 and visit Math Practice at <a href="mailto:gpescience.com">gpescience.com</a>.



**Topic: Weather Satellites**Visit **gpescience.com** for Web
links to information about how
weather satellites use thermal
energy to acquire weather data.

**Activity** Draw a diagram showing how a satellite uses thermal energy to produce images.

## **Thermal Energy**

According to the kinetic theory, atoms and molecules that make up matter are in constant motion. However, not only do these particles have kinetic energy due to their motion, they also have potential energy. This is because atoms and molecules exert attractive electric forces on each other. Recall that Earth exerts an attractive gravitational force on a ball. When the ball is above the ground, the ball and Earth are separated, and the ball has potential energy. In the same way, particles that exert attractive forces on each other have potential energy that increases as they get farther apart. The sum of the kinetic and potential energies of all the particles in an object is the **thermal energy** of the object. **Figure 2** shows how thermal energy depends on the kinetic and potential energies of the particles in a material.

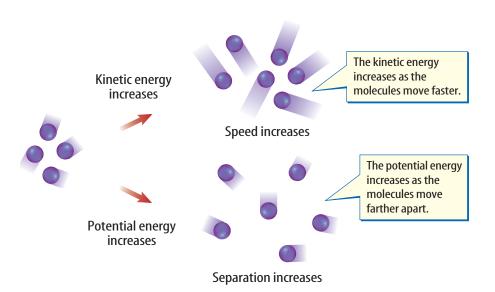


What type of energy results from the attractive forces between particles?

Thermal Energy of a Moving Object You've learned that the faster an object moves, the greater its kinetic energy. A ball rolling across the floor has greater kinetic energy than if it were sitting still. Does this mean that the rolling ball also has greater thermal energy? At first, the answer might seem to be yes, but in fact, the thermal energy is the same for both of the balls, if they are at the same temperature. Thermal energy is the sum of the kinetic energy and potential energy of the particles that make up the ball, not of the ball itself. The increase in the ball's speed doesn't affect the random motion of its particles, so it doesn't affect its thermal energy.

**Figure 2** The thermal energy of a substance is the sum of the kinetic and potential energies of its molecules.

**Infer** why increasing the temperature of an object increases its thermal energy.



### Heat

Can you tell if someone has been sitting in your chair? Perhaps you've noticed that your chair felt warm, and maybe you concluded that someone was sitting in it recently. The chair felt warmer because thermal energy from the person's body flowed to the chair, increasing the chair's temperature.

**Heat** is thermal energy that flows from something at a higher temperature to something at a lower temperature. Heat is a form of energy, so it is measured in joules. Thermal energy always flows from a warmer to a cooler material. How did the ice cream in **Figure 3** become cold? Thermal energy flowed from the warmer liquid ingredients to the cooler ice-and-salt mixture. The liquid ingredients lost enough thermal energy to become cold enough to freeze. Meanwhile, the ice-and-salt solution absorbed thermal energy, causing some of the ice to melt.



**Figure 3** Thermal energy flows from the warmer ingredients inside the container to the iceand-salt mixture around it.



Reading Checke How are heat and thermal energy related?

## **Specific Heat**

If you are at the beach in the summer, you might notice that the ocean seems cooler than the air or sand. Even though energy from the Sun goes to the air, sand, and water at the same rate, the water's temperature changes less than that of the air or sand.

As a substance is heated, its temperature change depends both on the amount of thermal energy added and the nature of the substance. For an equal mass of water and sand, about six times as much thermal energy is needed to raise the temperature of the water than the sand by 1°C. It's not surprising, then, that the sand feels much warmer than the ocean. The amount of thermal energy needed to raise the temperature of 1 kg of some material by 1°C is called the specific heat of the material. Specific heat is measured in joules per kilogram per degree Celsius, which is written as J/(kg °C). **Table 1** shows the specific heats of some familiar materials.



Reading Check What is the specific heat of a material?

Table 1 Specific Heat of Some Common Materials		
Substance	Specific Heat [J/(kg°C)]	
Water	4,184	
lce	2,110	
Asphalt	920	
Glass	800	
Iron	450	



Coastal Climates The high specific heat of water causes large bodies of water to heat up and cool down more slowly than land masses. As a result, the temperature changes in coastal areas tend to be less extreme than they are farther inland.

**Changes in Thermal Energy** The thermal energy of an object changes when its temperature changes. If *Q* is the change in thermal energy and *C* is the specific heat, the change in thermal energy can be calculated from the following equation:

### **Thermal Energy Equation**

change in thermal energy (J) = mass (kg)  $\times$  change in temperature (°C)  $\times$  specific heat  $\left(\frac{J}{kg^{\circ}C}\right)$ 

$$Q = m(T_{\rm f} - T_{\rm i})C$$

## Applying Math

### **Solve a Simple Equation**

**CHANGE IN THERMAL ENERGY** Find the change in thermal energy of a 20-kg wooden chair that warms from 15°C to 25°C if the specific heat of wood is 1,700 J/(kg °C).

### **IDENTIFY** known values and the unknown value

Identify the known values:

A wooden chair with a mass of 20 kg m = 20 kg

warms from 15°C to 25°C  $T_i = 15$ °C and  $T_f = 25$ °C

the specific heat of wood is 1,700 J/(kg °C) C = 1,700 J/(kg °C)

Identify the unknown value:

What is the change in thermal energy Q = ? J

### SOLVE the problem

Substitute the known values into the thermal energy equation:

$$Q = m(T_{f} - T_{i})C = (20 \text{ kg})(25^{\circ}\text{C} - 15^{\circ}\text{C})(1,700 \frac{\text{J}}{\text{kg}^{\circ}\text{C}})$$
$$= (20 \text{ kg})(10^{\circ}\text{C})(1,700 \frac{\text{J}}{\text{kg}^{\circ}\text{C}}) = 340,000 \text{ kg}^{\circ}\text{C} \frac{\text{J}}{\text{kg}^{\circ}\text{C}} = 340,000 \text{ J}$$

### **CHECK** your answer

Does your answer seem reasonable? Check your answer by dividing the change in thermal energy you calculated by the mass and the specific heat given in the problem. The result should be the difference in temperature given in the problem.

### **Practice Problems**

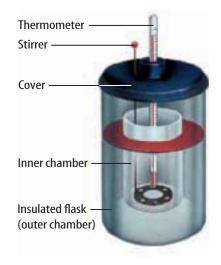
The air in a living room has a mass of 72 kg and a specific heat of 1,010 J/(kg °C). What is the change in thermal energy of the air when it warms from 20°C to 25°C?

For more practice problems, go to page 879 and visit Math Practice at <a href="mailto:gpescience.com">gpescience.com</a>.

## **Measuring Specific Heat**

The specific heat of a material can be measured using a device called a calorimeter, shown in **Figure 4.** The specific heat of a material can be determined if the mass of the material, its change in temperature, and the amount of thermal energy absorbed or released are known. In a calorimeter, a heated sample transfers thermal energy to a known mass of water. The energy absorbed by the water can be calculated by measuring the water's temperature change. The thermal energy released by the sample is equal to the thermal energy absorbed by the water.

**Using a Calorimeter** To measure the specific heat of a material, the mass of a sample of the material is measured, as is the initial temperature of the water in the calorimeter. The material then is heated, its temperature is measured, and the sample is placed in the water in the inner chamber of the calorimeter. The sample cools as thermal energy is transferred to the water, and the temperature of the water increases. The transfer continues until the sample and the water are at the same temperature. Then the initial and final temperatures of the water are known, and the thermal energy gained by the water can be calculated.



**Figure 4** A calorimeter can be used to measure the specific heat of materials. The sample is placed in the inner chamber.

### section

### Summary

### **Temperature**

- The kinetic theory is a description of how the particles in a material are moving.
- The temperature of an object is a measure of the average kinetic energy of the particles that make up the object.

### **Thermal Energy and Heat**

- Thermal energy is the sum of the kinetic and potential energies of the particles in an object.
- Heat is thermal energy that is transferred from an object at a higher temperature to an object at a lower temperature.

### **Specific Heat**

- The specific heat of a material is the amount of thermal energy needed to raise the temperature of 1 kg of the material by 1°C.
- The change in thermal energy of an object can be calculated from this equation:

$$Q = m(T_{\rm f} - T_{\rm i})C$$

# Self Check

review

- **1. Explain** how energy moves when you touch a block of ice with your hand.
- **2. Describe** how the thermal energy of an object changes when the object's temperature changes.
- **3. Infer** When thermal energy flows between two objects, does the temperature increase of one object always equal the temperature decrease of the other? Explain.
- **4. Describe** how the particles in matter move, using the assumptions of the kinetic theory.
- **5. Think Critically** Explain whether or not the following statement is true: For any two objects, the one with the higher temperature always has more thermal energy.

### **Applying Math**

- **6. Calculate** the change in thermal energy of the water in a pond with a mass of 1,000 kg and a specific heat of 4,184 J/(kg °C) if the water cools by 1°C.
- **7. Calculate** the specific heat of a metal if 0.5 kg absorbs 9,000 J of thermal energy as it warms by 10°C.

# **States of Matter**

## **Reading Guide**

### What You'll Learn

- Describe the differences in the four states of matter.
- Explain how the motion of particles in a material changes at the material's melting point and boiling point.
- **Explain** why thermal expansion occurs.

# Why It's Important

You can use energy that is lost or gained when a substance changes from one state to another.

### Review Vocabulary

force: a push or a pull that one object exerts on another

### **New Vocabulary**

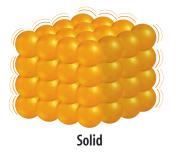
- plasma
- heat of fusion
- heat of vaporization

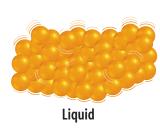
## **Four States of Matter**

Every day you encounter different states of matter. Your lunch probably includes a solid and a liquid, such as pizza and a drink. The air you breathe is a gas. The Sun, lightning, and fluorescent lights contain a fourth state of matter called plasma. The differences between solids, liquids and gases are due to differences in the attraction between particles.

**Solid State** The spacing between particles is different for solids, liquids, and gases, as shown in **Figure 5.** The particles of a solid are packed closely together and are constantly vibrating in place. Because the attractions between particles are strong, solids have a fixed volume and shape.

**Figure 5** In solids, strong attractive forces hold particles in place. Particles in liquids and gases do not have fixed arrangements. Particles are farther apart in gases than in solids and liquids.







**Liquid State** In a liquid the attractive forces between particles are weaker than in a solid. The particles can slide past each other, allowing liquids to flow and take the shape of their container. However, the attractive forces are strong enough to cause particles to cling together. As a result, liquids have a definite volume, but not a definite shape.

Reading Check Why do liquids flow?

**Gas State** In a gas, the particles are much farther apart than in a liquid or a solid. Because the particles are so far apart, the attractive forces between them are weak. In a gas the forces between particles are so weak that the particles no longer cling together. As a result, gases do not have a definite shape or volume.

Because the particles in a gas are so far apart, a gas contains mostly empty space. This means that the density of gases is much less than the density of solids and liquids. Also, the particles in a gas will spread throughout a given volume until they are distributed evenly. This process is called diffusion. Diffusion also occurs in solids and liquids, but occurs much more rapidly in gases.

**Plasma State** The most common state of matter in the universe is the

plasma state. Plasma is matter consisting of positively and negatively charged particles and does not have a definite shape or volume. It results from collisions between particles moving at such high speeds that electrons are knocked from the atoms, leaving only charged particles. All of the observed stars, including the Sun shown in **Figure 6**, contain plasma. Lightning bolts,

neon and fluorescent tubes, and auroras

also contain plasmas.

# **Changing States**

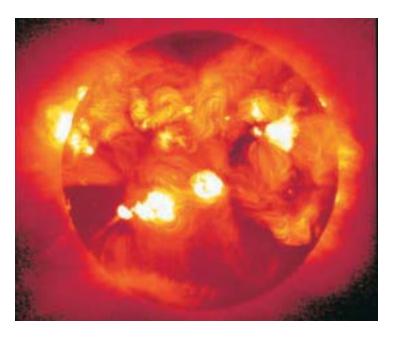
If you hold an ice cube in your hand, you can see it change from a solid to a liquid. A liquid changes to a gas when a puddle of water disappears after a rain on a hot day. Adding thermal energy caused the solid ice to change to a liquid and the liquid water to become a gas. Changes in the thermal energy of a material can cause it to change from one state to another.



**Topic: States of Matter** Visit gpescience.com for Web links to information about states of matter.

**Activity** Create a slide presentation about the states of matter using computer presentation software.

Figure 6 The Sun and other stars contain matter that is in the plasma state. Plasma usually exists where the temperature is extremely high. **Describe** the plasma state.





### **Comparing States** of Water

### **Procedure**

- 1. Fill a plastic bowl or ice tray with water. Mark the level of the top surface of the water with a **marker** or piece of masking tape.
- 2. Place the container in a freezer overnight.
- **3.** Remove the container from the freezer and observe the level of the ice that has formed.

### **Analysis**

- 1. How does the level of ice compare with the level of water that you placed in the container?
- **2.** Explain why the level of ice is different from the level of the water.

**Melting** What causes an ice cube to melt into liquid water? As the temperature of the ice increases, its particles move faster, and the attractive forces between them aren't strong enough to keep them in place. The particles can slip out of their ordered arrangement, and the ice melts. The temperature at which a solid begins to melt is its melting point. Energy is required for the particles to slip out of the ordered arrangement. The amount of energy required to change 1 kg of a substance from a solid to a liquid at its melting point is known as the **heat of fusion**.

**Freezing** The heat of fusion is also the energy released when a liquid freezes, or changes to a solid. If you lower a liquid's temperature, you decrease its particles' average kinetic energy, and they move slower. The attractive forces then are strong enough that the particles form an ordered arrangement.

**Vaporization** As the temperature of a liquid increases, the particles in the liquid move faster. As the particles move faster and become farther apart, the forces between them can become so weak that the particles no longer cling together. Then vaporization occurs as liquid changes into a gas. Vaporization can occur within the liquid or at the surface of the liquid. Vaporization that occurs at the surface of a liquid is called evaporation. Particles that enter the gas state have more energy than the particles left in the liquid. Evaporation causes the temperature of the liquid to decrease.

**Boiling** A second way that a liquid can vaporize is by boiling, shown in **Figure 7.** Unlike evaporation, boiling occurs throughout a liquid. It occurs only at a certain temperature depending on the pressure on the surface of the liquid. The boiling point of a liquid is the temperature at which the pressure of the vapor in the liquid is equal to the external pressure acting on its surface. This external pressure is a force pushing down upon a liquid, keeping particles from escaping. The **heat of vaporization** is the amount of energy required for 1 kg of the liquid at its boiling point to become a gas.

**Figure 7** Boiling occurs throughout a liquid when the pressure of the pockets of gas forming in the liquid equals the pressure of the vapor at the surface of the liquid.

**Explain** the difference between boiling and evaporation.



**Condensation** The heat of vaporization is also the amount of energy released during condensation, when a gas changes into a liquid. You've probably seen condensation form on the sides of a glass of ice water on a hot day. The cold glass reduced the temperature of nearby water vapor. The average kinetic energy of the water particles decreased, and the water vapor changed to a liquid. As shown in **Figure 8**, dew also is the result of condensation.



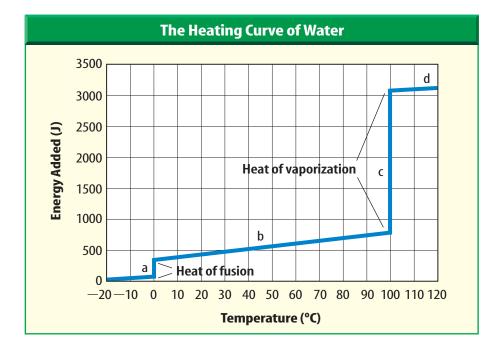
What change of state occurs during condensation?

**Heating Curve of a Substance** A graph representing water being heated from -20°C to 120°C is shown in **Figure 9.** This graph is called a heating curve because it shows the temperature change of water as thermal energy is added. There are two areas on the graph where the temperature does not change. One is at 0°C, where ice is melting. All of the energy absorbed by the ice at this temperature increases the potential energy of the water molecules. This causes water molecules to move farther apart and weakens the forces between molecules. However, the average kinetic energy of the water molecules doesn't change. As a result, the temperature remains constant during melting.

After the ice melts completely, adding additional energy causes the water molecules to move faster so that the temperature of the water increases. At 100°C, the water changes from a liquid to a gas. As the water absorbs energy, only the potential energy of the water molecules increases and the temperature of the water doesn't change. After the liquid water has changed completely into a gas, the temperature of the gas increases as energy is added.



**Figure 8** The formation of dew is an example of condensation. Dew forms when the air around matter, such as spider webs, cools enough so that water vapor in the air changes to a liquid. **Identify** *the change in state that* occurs when dew evaporates.



**Figure 9** This graph shows the heating curve of one gram of water from  $-20^{\circ}$ C to  $120^{\circ}$ C. At **a** and **c**, the energy absorbed causes water molecules to move faster and so the temperature increases. At **b** and **d**, the water changes from one state to another. The added energy increases the potential energy of the water molecules, but not the kinetic energy, so the temperature doesn't change.

**Figure 10** This expansion joint enables the road surface on this bridge to expand without causing the road surface to crack or buckle.



# **Thermal Expansion**

When you have gone over a highway bridge in a car, you might have noticed the gaps between sections of the bridge, such as the gap shown in **Figure 10.** This gap is called an expansion joint. The materials that make up the bridge and the road surface expand when they get warmer. Expansion joints provide space for these materials to expand on hot days without causing the materials to become warped or cracked.

**The Thermal Expansion of Matter** The kinetic theory explains why an object expands when its temperature increases. According to the kinetic theory, the particles in an object are in constant motion. The speed of these particles increases as the temperature of the object increases. As the particles move faster, the attractive forces between them become weaker and the distance between particles increases. The increased separation between the particles results in the expansion of the object and the size of the object increases. When a material cools, the particles in the material move more slowly and become closer together. As a result, the material contracts and its dimensions decrease.

Thermal Expansion of Liquids The forces between the particles in liquids are usually weaker than the forces between the particles in a solid. As a result, the same temperature increase usually causes liquids to expand much more than solids. For example, the liquid in the thermometer shown in **Figure 11** expands as its temperature increases. However, the dimensions of the glass tube containing the liquid hardly change at all. This causes the height of the liquid column in the tube to increase as the temperature of the liquid increases. If the glass tube expanded as much as the liquid, the height of the liquid column wouldn't change as the temperature changed.

**Figure 11** The liquid in the thermometer tube expands as its temperature increases. Because the tube expands much less than the liquid, the height of the liquid column increases as the temperature increases.



**Thermal Expansion of Gases** In a gas, the forces between particles are much weaker than they are in liquids. As a result, gases expand even more than liquids for the same increase in temperature. When thermal expansion occurs, the volume of the material increases. Recall that the density of an object is the mass of the object divided by its volume. Because the material's volume has increased, but its mass hasn't changed, the material becomes less dense as it expands.



How does the density of a material change when the material expands?

The decrease in density caused by thermal expansion enables the hot-air balloon in **Figure 12** to rise. The air inside the balloon is heated by a burner. The hot air in the balloon expands and becomes less dense than the cooler air outside the balloon. As a result, the hot-air balloon is pushed upward by the denser, cooler air around it.

**Figure 12** The air inside the hot-air balloon expands as it is heated. Its density decreases and the balloon rises.



## section

# review

### Summary

### **Four States of Matter**

- In solids, particles are held in place by strong attractive forces. Solids have a definite volume and shape.
- In liquids, the attractive forces are weaker and particles can move past each other. Liquids have a definite volume, but no definite shape.
- In gases, the attractive forces between particles are weakest. Gases have neither a definite volume nor shape.
- A plasma is made of electrically charged particles.

### **Changing States**

- The heat of fusion is the amount of energy needed to change 1 kg of a material at its melting point from a solid to a liquid.
- The heat of vaporization is the amount of energy needed to change 1 kg of material at its boiling point from a liquid to a gas.

### **Self Check**

- 1. Compare and contrast solids, liquids, gases, and plasma.
- **2. Explain** whether the temperature of a substance must increase when thermal energy is added to the substance.
- 3. Explain how the forces between water molecules in an ice cube change when the ice cube melts.
- 4. Think Critically The atmospheric pressure on a mountain peak is lower than the atmospheric pressure at sea level. Compare the boiling point of water at sea level to its boiling point on the mountain peak.

### **Applying Math**

- **5. Calculate** the amount of thermal energy required to change a 0.45-kg block of ice at 0°C to water at 0°C if the heat of fusion of water is 334,000 J/kg.
- **6. Calculate** The heat of vaporization for water is  $2.26 \times 10^6$  J/kg. What mass of liquid water at 100°C can be changed to water vapor at 100°C by adding  $1.0 \times 10^6$  J of thermal energy to the liquid water?

# **Transferring Thermal Energy**

# **Reading Guide**

#### What You'll Learn

- Compare and contrast the transfer of thermal energy by conduction, convection, and radiation.
- Compare and contrast thermal conductors and insulators.
- **Explain** how thermal insulators are used to control the transfer of thermal energy.

# Why It's Important

You must be able to control the flow of thermal energy to keep from being too hot or too cold.

#### Review Vocabulary

density: the mass per unit volume of a substance

#### **New Vocabulary**

- conduction
- convection
- radiation
- thermal insulator

Figure 13 Conduction occurs within the metal of this pot as faster-moving particles transfer thermal energy when they collide with slower-moving particles.



# **Ways to Transfer Thermal Energy**

When water is heated on a stove or when a hot slice of pizza becomes cool enough to eat, thermal energy is transferred from one place to another. Thermal energy can be transferred from one place to another by conduction, convection, or radiation.

#### Conduction

According to the kinetic theory, particles in matter are always in random motion. Thermal energy can be transferred

> when particles collide. This transfer of thermal energy between colliding particles is conduction. Figure 13 shows a metal pot being heated over a fire. The metal atoms nearest the fire absorb the most thermal energy, causing their kinetic energy to increase. Kinetic energy is transferred when these faster-moving atoms collide with slower-moving particles. As these collisions continue, thermal energy is transferred throughout the pot. When thermal energy is transferred by conduction, it is transferred by the collisions between particles, not by the movement of matter.

**Thermal Conductors** Thermal energy can be transferred by conduction in all materials. However, the rate at which thermal energy is transferred depends on the material. A material in which thermal energy is transferred easily is called a thermal conductor. The conduction of thermal energy in solids and liquids is faster than in gases. Particles in gases are farther apart than in solids or liquids and collide less frequently. Therefore, gases are poorer thermal conductors than solids or liquids. Solids usually are better thermal conductors than liquids or gases. The best thermal conductors are metals.

#### **Convection**

Unlike solids, liquids and gases can flow and are classified as fluids. In fluids, thermal energy can be transferred by convection. **Convection** is the transfer of thermal energy in a fluid by the movement of fluid from place to place. When convection occurs, particles with more energy transfer energy to other particles in the fluid as they move from place to place.

As the particles move faster, they tend to be farther apart. As a result, a fluid expands as its temperature increases. Recall that density is the mass of a material divided by its volume. When a fluid expands, its volume increases, but its mass doesn't change. The density of the fluid therefore decreases. The same is true for parts of a fluid that have been heated. The density of the warmer fluid is less than that of the surrounding cooler fluid.

**Convection Currents** The difference in densities between warmer and cooler fluids can cause convection currents to occur.

Figure 14 shows the formation of convection currents in a beaker of water that is being heated from the bottom. Warm water at the bottom of the beaker is less dense than the cooler water above it. Because the warmer water is less dense, it is forced upward by the sinking cooler water. As it rises, the warm water transfers thermal energy to the cooler water around it. When the warm water cools, it becomes denser than the surrounding warmer water and sinks to the bottom of the beaker. The rising and sinking water forms a convection current. In this way, convection currents transfer thermal energy by the movement of water from place to place.

Figure 14 Convection currents result when heated fluid rises and cooler fluid sinks.



#### **Comparing Thermal Conductors**

#### Procedure

- 1. Obtain a plastic spoon, a metal spoon, and a wooden spoon with similar lengths.
- 2. Stick a small plastic bead to the handle of each spoon with a dab of butter or wax. Each bead should be the same distance from the tip of the spoon.
- 3. Stand the spoons in a beaker, with the beads hanging over the edge of the beaker.
- 4. Carefully pour about 5 cm of **boiling water** in the beaker holding the spoons.

#### **Analysis**

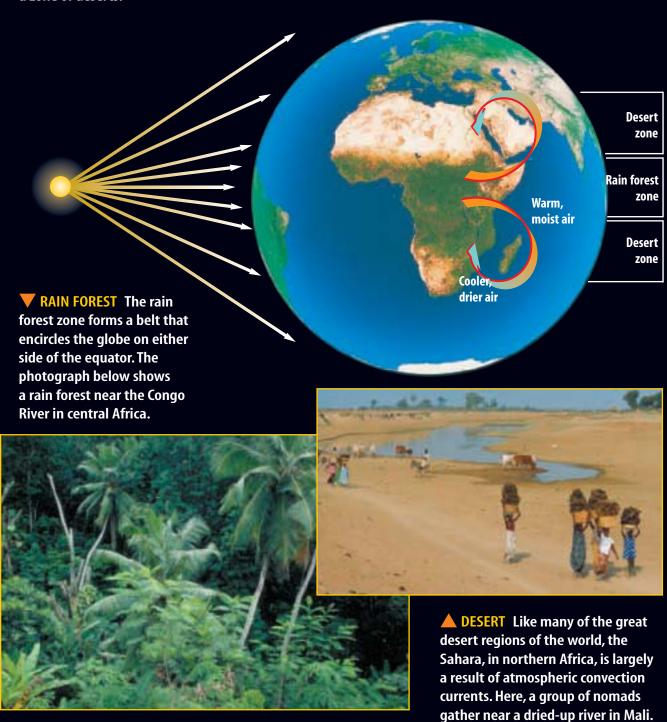
- 1. Describe how heat was transferred from the water to the beads.
- 2. Rank the spoons in their ability to conduct heat.



# NATIONAL GEOGRAPHIC VISUALIZING CONVECTION CURRENTS

#### Figure 15

hen the Sun beats down on the equator, warm, moist air begins to rise. As it rises, the air cools and loses its moisture as rain that sustains rain forests near the equator. Convection currents carry the now dry air farther north and south. Some of this dry air descends at the tropics, where it creates a zone of deserts.



**Deserts and Rain Forests** Earth's atmosphere is made of various gases and is a fluid. The atmosphere is warmer at the equator than it is at the north and south poles. Also, the atmosphere is warmer at Earth's surface than at higher altitudes. These temperature differences create convection currents that transfer thermal energy to cooler regions. **Figure 15** shows how these currents create rain forests and deserts in different regions.

## **Radiation**

Earth is warmed by energy from the Sun, but how does that energy travel through space? Almost no matter exists in the space between Earth and the Sun, so thermal energy cannot be transferred by conduction or convection. Instead, the Sun's energy reaches Earth by radiation.

**Radiation** is the transfer of energy by electromagnetic waves. These waves travel through space even when no matter is present. Energy transferred by radiation often is called radiant energy. When you stand near a fire, much of the warmth you feel is caused by radiation transferring thermal energy to your skin. Radiation can pass through solids, liquids, and gases, but the transfer of energy by radiation is most important in gases.

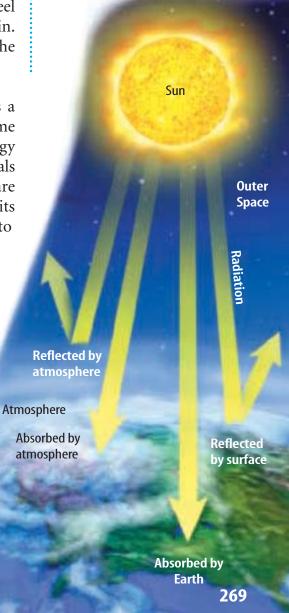
Radiant Energy and Matter When radiation strikes a material, some energy is absorbed, some is reflected, and some may be transmitted through the material. The amount of energy that does each depends on the material. Light-colored materials reflect more radiant energy, while dark-colored materials are more absorbent. When a material absorbs radiant energy, its thermal energy increases. **Figure 16** shows what happens to radiant energy from the Sun as it reaches Earth.

For example, when a car sits out in the Sun, some of the Sun's radiation passes through the car windows. Materials inside the car absorb some of this radiation and become hot.

# **The Flow of Thermal Energy**

You do a number of things every day to control the flow of thermal energy. When it's cold outside you wear a coat. You use an oven mitt when handling a hot dish. In each case, you use an insulating material to help reduce the flow of thermal energy. Your coat keeps you warm by reducing the flow of thermal energy from your body to the surrounding air. The oven mitt keeps your hand from being burned by reducing the flow of thermal energy from the hot dish to your hand.

**Figure 16** Not all of the Sun's radiant energy reaches Earth's surface. Some of it is reflected or absorbed by the atmosphere. Even some of the radiation that reaches Earth's surface is reflected.





**Figure 17** The fibers of this insulating material contain air spaces that are good thermal insulators. They reduce the rate at which thermal energy flows in the material.

#### **Thermal Insulators**

A jacket and an oven mitt are examples of thermal insulators. A material in which thermal energy moves slowly is a **thermal insulator**. Examples of materials that are thermal insulators are wood, some plastics, fiberglass, and air. Materials that are good conductors of thermal energy, such as metals, are poor thermal insulators.

Gases, such as air, are usually much better thermal insulators than solids or liquids. Some types of insulating material contain many pockets of trapped air. These air pockets are poor conductors

of thermal energy and also keep convection currents from forming. Winter jackets often are made of insulating materials consisting of fibers, like the ones shown in Figure 17, that trap air and hold it next to you. This trapped air slows the flow of your body heat to the colder air outside the jacket. Gradually, the air trapped by the material is warmed by your body heat. Underneath the jacket you are wrapped in a blanket of warm air.



Reading Check Why is a material that traps air a good insulator?

# section

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#### **Summary**

#### **Conduction**

- Conduction is the transfer of thermal energy by collisions between particles.
- Conduction occurs in solids, liquids, and gases. Metals are the best conductors of heat.

#### **Convection**

- Convection is the transfer of thermal energy by the movement of warmer and cooler material.
- Convection occurs in fluids. Rising of warmer fluid and sinking of cooler fluid forms a convection current.

#### **Radiation**

 Radiation is the transfer of energy by electromagnetic waves.

#### **Thermal Insulators**

 Thermal energy moves slowly in thermal insulators. Thermal insulators are used to control the flow of thermal energy.

#### **Self Check**

- 1. Explain why convection can occur in fluids but not in solids.
- 2. Explain why the air temperature near the ceiling of a room tends to be warmer than near the floor.
- 3. Predict whether plastic foam, which contains pockets of air, would be a good conductor or a good insulator.
- 4. **Describe** how a convection current occurs.
- **5. Think Critically** Several days after a snowfall, the roofs of some homes on a street have almost no snow on them, while the roofs of other houses are still snow covered. Describe what would cause this difference.

#### Applying Math

**6. Calculate Solar Radiation** Averaged over a year in the central United States, radiation from the Sun transfers about 200 W to each square meter of Earth's surface. If a house is 10 m long by 10 m wide, how much solar energy falls on the house each second?



A hawk gliding through the sky will rarely flap its wings. Hawks and some other birds conserve energy by gliding on columns of warm air rising up from the ground. These convection currents form when gases or liquids are heated unevenly and the warmer, less dense fluid is forced upward.

# 👂 Real-World Problem

How can convection currents be modeled and observed?

#### Goals

- Model the formation of convection currents in water.
- Observe convection currents formed in
- Observe convection currents formed in air.

#### **Materials**

burner or hot plate water candle

500-mL beaker black pepper



**WARNING:** Use care when working with hot materials. Remember that hot and cold glass appear the same.

#### **Procedure**

- 1. Pour 450 mL of water into the beaker.
- **2.** Use a balance to measure 1 g of black pepper.
- **3.** Sprinkle the pepper into the beaker of water and let it settle to the bottom of the beaker.

- 4. Heat the bottom of the beaker using the burner or the hotplate.
- **5. Observe** how the particles of pepper move as the water is heated and make a drawing showing their motion in your Science Journal.
- 6. Turn off the hot plate or burner. Light the candle and let it burn for a few minutes.
- 7. Blow out the candle and observe the motion of the smoke.
- **8.** Make a drawing of the movement of the smoke in your Science Journal.

# Conclude and Apply

- 1. **Describe** how the particles of pepper moved as the water became hotter.
- 2. Explain how the motion of the pepper particles is related to the motion of the water.
- 3. Explain how a convection current formed in the beaker.
- **4. Explain** why the motion of the pepper changed when the heat was turned off.
- 5. **Predict** how the pepper would move if the water were heated from the top.
- **6. Describe** how the smoke particles moved when the candle was blown out.
- **7. Explain** why the smoke moved as it did.



**Compare** your conclusions with other students in your class.

# **Using Thermal Energy**

# **Reading Guide**

# What You'll Learn

- Describe the first and second laws of thermodynamics.
- **Explain** how an internal combustion engine converts thermal energy to mechanical energy.
- **Describe** how the entropy of the universe changes when any event occurs.

# Why It's Important

Imagine your life without heating systems, cooling systems, or cars.

#### Review Vocabulary

work: the product of the force exerted on an object and the distance the object moves in the direction of the force

#### New Vocabulary

- first law of thermodynamics
- second law of thermodynamics
- entropy

# **How is thermal energy used?**

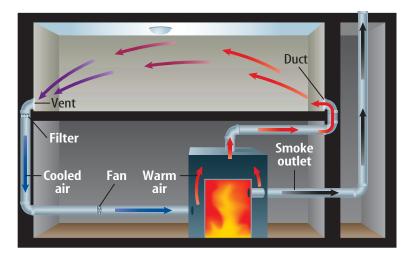
If you've ever lit a campfire to keep warm or turned on a stove to boil water, you've used thermal energy. Heating a house and using a gasoline engine to mow a lawn are other ways that thermal energy is used. Sometimes thermal energy is transferred to an object to heat it, as when water is boiled or a room is heated. Sometimes thermal energy is converted into work.

# **Heating Systems**

Almost everywhere in the United States a heating system is needed to make indoor temperatures comfortable on cold days. Heating systems add thermal energy to the interiors of rooms. The

best heating system for a building depends on the local climate and how the building is constructed.

**Figure 18** In a forced-air system, heated air is blown through ducts that lead to rooms in the building.



**Forced-Air Systems** The most common type of heating system in use today is the forced-air system, as shown in **Figure 18.** In this system, fuel is burned in a furnace and heats a volume of air. A fan blows the heated air through a series of large pipes called ducts. The ducts lead to openings called vents in each room. Cool air is returned through additional vents to the furnace, where it is reheated.

**Radiator Systems** Before forced-air systems were widely used, many homes and buildings were heated by radiators. A radiator is a closed metal container that contains hot water or steam. The thermal energy contained in the hot water or steam is transferred to the air surrounding the radiator by conduction. This warm air then moves through the room by convection.

In radiator heating systems, fuel burned in a central furnace heats a tank of water. A system of pipes carries the hot water to radiators in the rooms of the building. After the water cools, it flows through the pipes back to the water tank, and is reheated.

**Electric Heating Systems** Unlike forced-air and radiator systems, electric heaters, like the one in Figure 19, convert electrical energy to thermal energy. In an electric heating system, electrically heated coils placed in floors and in walls heat the surrounding air by conduction and convection. Electric heating systems are not as widely used as forced-air systems. However, in warmer climates the walls and floors of some buildings may not be thick enough to contain pipes and ducts. Then an electric heating system might be the only practical way to provide heat.

# **Thermodynamics**

There is another way to increase the thermal energy of an object besides heating it. Have you ever rubbed your hands together to warm them on a cold day? Your hands get warmer and their thermal energy and temperature increase. You did work on your hands by rubbing them together. The work you did caused the thermal energy of your hands to increase. Thermal energy, heat, and work are related. The study of the relationship among thermal energy, heat, and work is thermodynamics.

Heating and Work Increase Thermal Energy You can warm your hands by placing them near a fire. Thermal energy is added to your hands by radiation. You can make your hands even warmer by rubbing them together and holding them near a fire. Both the work you do and energy from the fire increase the thermal energy of your hands.

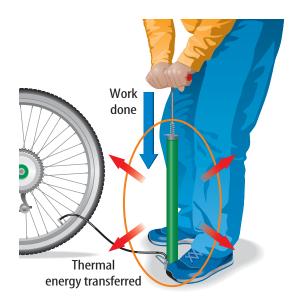
In the example above, your hands can be considered as a system. A system can be a group of objects, such as a galaxy or a car's engine, or something as simple as a ball. In fact, a system is anything you can draw a boundary around. The energy transferred to a system is the amount of energy flowing into the system across the boundary. Heating a system transfers energy to the system. The work done on a system is the work done by something outside the system's boundary.



Figure 19 Electric heaters convert electrical energy to thermal energy. Thermal energy is transferred to the room mainly by radiation and convection.



Thermodynamics and the Steam Engine By the end of the eighteenth century, the steam engine was being used in manufacturing and transportation, leading to a wide-spread change in society called the industrial revolution. A young French engineer named Sadi Carnot (1796-1832) studied how the efficiency of steam engines could be improved. His work provided the basis for the development of thermodynamics by others in the nineteenth century. Research the life of Sadi Carnot and write a paragraph describing the results of his studies.



**Figure 20** A bicycle air pump can be a system. Work is done on the system by pushing down on the handle. This causes the pump to become warm and thermal energy is transferred from the system to the air around it. **Infer** if the air pump is an open or a closed system.



Visit **gpescience.com** for Web links to information about heating systems that use solar energy to heat buildings.

**Activity** Draw a diagram showing how an active solar heating system is used to heat a home.

**The First Law of Thermodynamics** According to the first law of thermodynamics, the increase in thermal energy of a system equals the work done on the system plus the thermal energy transferred to the system. Doing work on a system is a way of adding energy to a system, as shown in Figure 20. As a result, the temperature of a system can be increased by heating the system, doing work on the system, or both. The first law of thermodynamics is another way of stating the law of conservation of energy. The increase in energy of a system equals the energy added to the system.

**Closed and Open Systems** A system is an open system if thermal energy flows across the boundary or if work is done across the boundary. The energy of an

open system can change. If no thermal energy flows across the boundary and no outside work is done, the system is a closed system. According to the first law of thermodynamics, the thermal energy of a closed system doesn't change. Energy might change form within the system, but the total energy of the system doesn't change.

The Second Law of Thermodynamics When thermal energy flows from a warm object to a cool object, the first law of thermodynamics is satisfied. The increase in thermal energy of the cool object equals the decrease in thermal energy of the warm object. Energy is neither created or destroyed.



How does the flow of thermal energy from a warm object to a cool object satisfy the first law of thermodynamics?

Can thermal energy flow spontaneously from a cool object to a warm object? This never happens, but it doesn't violate the first law of thermodynamics. The first law requires only that energy be conserved. The first law would be satisfied if the decrease in thermal energy of the cool object equaled the increase in thermal energy of the warm object.

However, the flow of thermal energy spontaneously from a cool object to a warm object never happens because it violates another law—the second law of thermodynamics. One way to state the **second law of thermodynamics** is that it is impossible for thermal energy to flow from a cool object to a warmer object unless work is done. For example, if you hold an ice cube in your hand, no work is done. As a result, thermal energy flows only from your warmer hand to the colder ice.

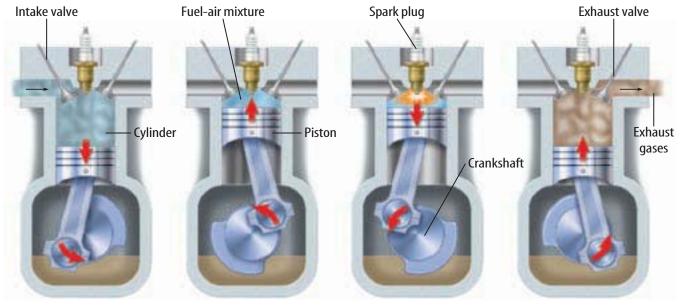
# **Converting Thermal Energy to Work**

If you give a book sitting on a table a push, the book slides for a while and then stops. Friction between the book and the table converts all of the work you did on the book into thermal energy. Is it possible to convert thermal energy completely into work? Even though this process wouldn't violate the first law of thermodynamics, it violates the second law of thermodynamics. No device or process can convert thermal energy completely into work.

**Heat Engines** A device that converts thermal energy into work is called a heat engine. A car's engine is a heat engine. It converts some of the thermal energy produced by burning fuel into work that causes the car to move. However, only about 25 percent of the thermal energy in the burning fuel is converted into work. The rest of the thermal energy is transferred to the air surrounding the engine. When thermal energy is converted into work, some thermal energy always is transferred to the surroundings.

**Internal Combustion Engines** The heat engine in a car is an internal combustion engine, in which fuel is burned inside the engine in chambers or cylinders. Each cylinder contains a piston that moves up and down. Each up or down movement of the piston is called a stroke. Automobile and diesel engines make four different strokes, as shown in Figure 21.

**Figure 21** The up-and-down movement of a piston in an automobile engine consists of four separate strokes. The four strokes form a cycle that is repeated many times each second by each piston.



Intake stroke

The intake valve opens as the piston moves downward, drawing gasoline and air into the cylinder.

**Compression stroke** 

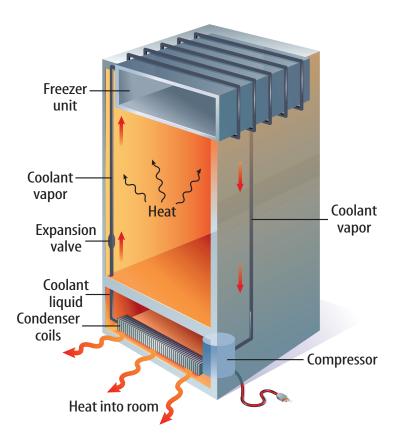
The intake valve closes as the piston moves upward, compressing the fuel-air mixture.

Power stroke

A spark plug ignites the fuel-air mixture. The hot gases expand, pushing the piston down.

**Exhaust stroke** 

As the piston moves up, the exhaust valve opens, and the hot gases are pushed out of the cylinder.



**Figure 22** A refrigerator does work on the coolant in order to transfer thermal energy from inside the refrigerator to the warmer air outside. Work is done when the compressor compresses the coolant, causing its temperature to increase.

# **Moving Thermal Energy**

How do refrigerators stay cold? The second law of thermodynamics prevents thermal energy from spontaneously flowing from inside the refrigerator to the warmer room. However, the second law of thermodynamics allows thermal energy to be moved from a cold area to a warmer area if work is done in the process. A refrigerator does work as it moves thermal energy from inside the refrigerator to the warmer room. The energy to do the work comes from the electrical energy the refrigerator obtains from an electric outlet.

**Refrigerators** A refrigerator contains a coolant that is pumped through pipes in the refrigerator. The coolant is a special substance that evaporates at a low temperature. **Figure 22** shows how a refrigerator operates. Liquid coolant is

pumped through an expansion valve and changes into a gas. When the coolant changes to a gas, it cools. The cold gas is pumped through pipes inside the refrigerator. The coolant absorbs thermal energy and the inside of the refrigerator cools.

The gas then is pumped to a compressor that does work by compressing the gas. This makes the coolant gas warmer than the room. The warm gas then flows through condenser coils. There thermal energy flows from the gas to the air in the room. Some of this thermal energy is the thermal energy the coolant gas absorbed from inside the refrigerator. As the gas gives off thermal energy, it cools and changes into a liquid. Then liquid coolant is changed back into a gas, and the cycle is repeated.

# **Entropy**

According to the laws of thermodynamics, work can be converted completely into thermal energy, but thermal energy can't be converted completely into work. What prevents thermal energy from being converted completely into work? The answer has to do with entropy. **Entropy** is a measure of how spread out, or dispersed, energy is. Entropy increases when energy becomes more spread out and less concentrated. Converting thermal energy completely into work causes energy to become less spread out and more concentrated. As a result, entropy decreases.

**Entropy Always Increases** All events that occur, such as the production of work in an automobile engine, must obey the entropy principle. According to the entropy principle, all events that occur cause the entropy of the universe to increase. This means that all events cause energy to spread out and become less concentrated. Figure 23 shows how the potential energy stored in a ball becomes less concentrated when the ball is dropped and hits the ground.

How does an automobile engine cause entropy to increase? The energy source in an automobile engine is the chemical potential energy concentrated in the gasoline in the fuel tank. When gasoline is burned in the cylinders, 75 percent of the thermal energy produced is not converted into work, but spreads out into the air surrounding the car. Because energy becomes more spread out, entropy increases. However, the energy that becomes spread out is no longer useable. Any event that occurs causes the amount of useable energy to decrease.

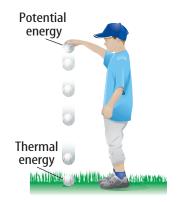


Figure 23 When the ball hits the ground, the potential energy it initially had is converted into thermal energy. This thermal energy spreads out and becomes less concentrated. This causes entropy to increase.

# section

#### review

#### **Summary**

#### **Heating Systems**

- A forced-air heating system uses a fan to force air heated by a furnace through a system of ducts.
- Heating systems transfer thermal energy to rooms by conduction and convection.

#### **Thermodynamics**

- The first law of thermodynamics states that the increase in thermal energy of a system equals the work done on the system plus the thermal energy added to the system.
- One way to state the second law of thermodynamics is that thermal energy will not flow from a hot to a cold object unless work is done.

#### **Converting Thermal Energy to Work**

- The second law of thermodynamics states that thermal energy cannot be converted completely into work.
- Entropy is a measure of how spread out or dispersed energy is. Entropy increases when thermal energy is produced in an energy transformation.
- According to the entropy principle, all events that occur cause the entropy of the universe to increase. As a result, the amount of usable energy decreases.

#### Self Check

- 1. Explain how the thermal energy of a closed system changes with time.
- **2. Compare and contrast** a forced-air heating system with a radiator system.
- 3. Explain whether or not a heat engine could be made 100 percent efficient by eliminating friction.
- **4. Explain** Use the entropy principle to explain why thermal energy can never be converted completely into work.
- **5. Think Critically** Suppose you vigorously shake a bottle of fruit juice. Predict how the temperature of the juice will change. Explain your reasoning.

#### **Applying Math**

- 6. Calculate Change in Thermal Energy You push down on the handle of a bicycle pump with a force of 20 N. The handle moves 0.3 m, and the pump does not absorb or release any thermal energy. What is the change in thermal energy of the bicycle pump as a result of the work you did on it?
- 7. Calculate Work The thermal energy released when a gallon of gasoline is burned in a car's engine is 140 million J. If the engine is 25 percent efficient, how much work does it do when one gallon of gasoline is burned?



# Conduction in Gases

#### Goals

- **Measure** temperature changes in air near a heat source.
- Observe conduction of heat in air.

#### **Materials**

thermometers (3) foam cups (2) 400-mL beakers (2) burner or hot plate paring knife thermal mitts (2)

#### **Safety Precautions**



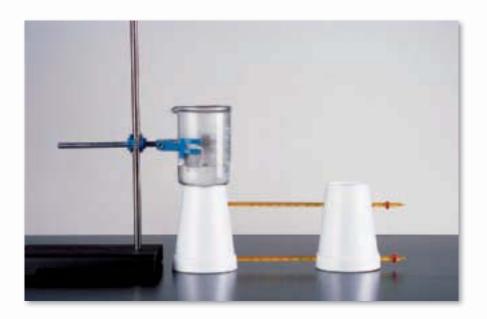
WARNING: Use care when handling hot water. Pour hot water using both hands.

# Real-World Problem

Does smog occur where you live? If so, you may have experienced a temperature inversion. Usually the Sun warms the ground and the air above it. When the air near the ground is warmer than the air above, convection occurs. This convection also carries smoke and other gases emitted by cars, chimneys, and smokestacks upward into the atmosphere. If the air near the ground is colder than the air above, convection does not occur. Then smoke and other pollutants can be trapped near the ground, sometimes forming smog. How do the insulating properties of air cause a temperature inversion to occur?

# Procedure

- 1. Using the paring knife, carefully cut the bottom from one foam cup.
- 2. Use a pencil or pen to poke holes about 2 cm from the top and bottom of each foam cup, as shown in the photo.
- 3. Turn both cups upside down, and poke the ends of the thermometers through the upper holes and lower holes, so both thermometers are supported horizontally. The bulb end of each thermometer should extend into the middle of the bottomless cup.



# Using Scientific Methods

- **4.** Heat about 350 mL of water to about 80°C in one of the beakers.
- **5.** Place an empty 400-mL beaker on top of the bottomless cup. Record the temperatures of the two thermometers in a data table like the one shown here.
- **6.** Add about 100 mL of hot water to the empty beaker. After one minute, record the temperatures of the thermometers in your data table.
- **7.** Continue to record the temperatures every minute for 10 min. Add hot water as needed to keep the temperature of the water at about 80°C.

Air Temperatures in Foam Cup					
Time (min)	Upper Thermometer (°C)	Lower Thermometer (°C)			
0					
1	Do not writ	te in this book.			
2					
3					
4					
5					

# Analyze Your Data

- **1. Graph** the temperatures measured by the upper and lower thermometers on the same graph. Make the vertical axis the temperature and the horizontal axis the time.
- **2. Calculate** the total temperature change for each thermometer by subtracting the initial temperature from the final temperature.
- **3. Calculate** the average rate of temperature change for each thermometer by dividing the total temperature change by 10 min.

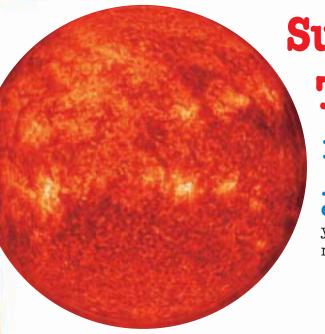
# Conclude and Apply

- **1. Explain** whether convection can occur in the foam cup if it's being heated from the top.
- **2. Describe** how heat was transferred through the air in the foam cup.
- **3. Explain** why the average rates of temperature change were different for the two thermometers.



**Compare** your results with other students in your class. **Identify** the factors that caused the average rate of temperature change to be different for different groups.

# SCIENCE Stats



# Surprising Thermal Energy

Did you know...

... The average amount of solar energy that reaches the United States each year is about 600 times greater than the nation's annual energy demands.

... When a space shuttle reenters Earth's atmosphere at more than 28,000 km/h, its outer

surface is heated by friction to nearly 1,650°C. This temperature is high enough to melt steel.



... A lightning bolt heats the air in its path to temperatures of about 25,000°C. That's about 4 times hotter than the average temperature on the surface of the Sun.

## **Applying Math**

- 1. The highest recorded temperature on Earth is 58°C and the lowest is -89°C. What is the range between the highest and lowest recorded temperatures?
- 2. What is the average temperature of the surface of the Sun? Draw a bar graph comparing the temperature of a lightning bolt to the temperature of the surface of the Sun.
- 5. The Sun is almost 150 million km from Earth. How long does it take solar energy to reach Earth if the energy travels at 300,000 km/s?

## **Reviewing Main Ideas**

#### Section 1

#### **Temperature and Thermal Energy**

- **1.** According to the kinetic theory, all matter is made of constantly moving particles that collide without losing energy.
- **2.** The temperature of a material is a measure of the average kinetic energy of the particles in the material.
- **3.** The thermal energy of an object is the total kinetic and potential energies of the particles in the object.
- 4. Heat is thermal energy that flows from a higher to a lower temperature.
- **5.** The specific heat is the amount of energy needed to raise the temperature of 1 kg of a substance by 1°C.

#### **Section 2 States of Matter**

- 1. The states of matter are solid, liquid, gas, and plasma.
- **2.** Changes of state can be interpreted in terms of the kinetic theory of matter.
- **3.** Most matter expands when heated and contracts when cooled. An expansion joint allows concrete to expand and contract without damage.



# Section 3

#### **Transferring Thermal Energy**

**1.** Conduction occurs when thermal energy is transferred by collisions between particles. Matter is not transferred.

- **2.** Convection occurs in a fluid as warmer and cooler fluid move from place to place.
- **3.** Radiation is the transfer of energy by electromagnetic waves. Radiation can transfer energy through empty space.
- **4.** Thermal energy flows more quickly in materials that are conductors than in insulators.
- **5.** Some insulating materials contain pockets of air that reduce the flow of thermal energy.

#### Section 4

#### **Using Thermal Energy**

- 1. According to the first law of thermodynamics, the increase in the thermal energy of a system equals the work done and the amount of thermal energy added to the system.
- **2.** The second law of thermodynamics states that thermal
  - energy cannot flow from a colder to a hotter temperature unless work is done.
- **3.** Any event that occurs decreases the amount of usable energy and increases the entropy of the universe.

FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review thermal energy.



## **Using Vocabulary**

conduction p. 266
convection p. 267
entropy p. 276
first law of
thermodynamics p. 274
heat p. 257
heat of fusion p. 262
heat of vaporization p. 262
Kelvin p. 255

kinetic theory p.254
plasma p.261
radiation p.269
second law of
thermodynamics p.274
specific heat p.257
temperature p.255
thermal energy p.256
thermal insulator p.270

Complete each statement using a word or phrase from the vocabulary list above.

- **1.** Thermal energy that is transferred from warmer to cooler materials is
- **2.** \_\_\_\_\_ is a measure of the average kinetic energy of the particles in a material.
- **3.** The energy required to raise the temperature of 1 kg of a material 1°C is a material's
- **4.** In \_\_\_\_\_\_, thermal energy is transferred by the collisions between particles, not by the transfer of matter.
- **5.** \_\_\_\_\_\_ is the theory used to explain the behavior of particles in matter.
- **6.** The transfer of energy by electromagnetic waves is \_\_\_\_\_.

#### **Checking Concepts**

Choose the word or phrase that best answers the question.

- **7.** Which is NOT a method of heat transfer?
  - **A)** conduction
- **c)** radiation
- **B)** convection
- **D)** specific heat
- **8.** Which state of matter is made of electrically charged particles?
  - A) gas
- c) plasma
- **B)** liquid
- **D)** solid

- **9.** During which phase of a four-stroke engine are waste gases removed?
  - A) combustion stroke
  - B) exhaust stroke
  - c) intake stroke
  - **D)** power stroke

Use the table below to answer question 10.

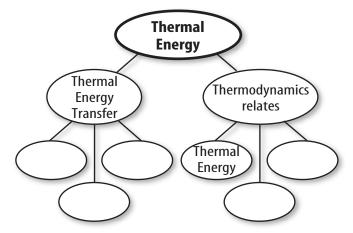
Latent Heats				
Substance	Heat of Fusion (J/g)	Heat of Vaporization (J/g)		
Ethanol	109	838		
Water	334	2,258		
Aluminum	397	10,900		
Propane	61	387		

- **10.** Which material would require the least amount of energy to change 1 kg from a solid to a liquid?
  - A) aluminum
- **c)** propane
- **B)** ethanol
- **D)** water
- **11.** Which of the following is a measure of the average kinetic energy of the particles in an object?
  - **A)** potential energy
  - **B)** specific heat
  - **c)** temperature
  - **D)** thermal energy
- **12.** Which of these is NOT used to calculate change in thermal energy?
  - A) mass
  - **B)** specific heat
  - **c)** temperature change
  - **D)** volume
- **13.** Which of the following processes does NOT require the presence of particles of matter?
  - A) combustion
  - **B)** conduction
  - **C)** convection
  - **D)** radiation

- **14.** Which of the following is the name for thermal energy that is transferred only from a higher temperature to a lower temperature?
  - A) heat
- **C)** potential energy
- **B)** kinetic energy
- **D)** solar energy
- **15.** According to the entropy principle, any event that occurs in the universe must cause which of the following to happen?
  - A) energy to become more concentrated
  - **B)** energy to become less concentrated
  - **C)** total amount of energy to increase
  - **D)** total amount of energy to decrease

#### **Interpreting Graphics**

**16.** Copy and complete this concept map.



# **Thinking Critically**

- 17. Explain On a hot day a friend suggests that you can make your kitchen cooler by leaving the refrigerator door open. Explain whether leaving the refrigerator door open would cause the air temperature in the kitchen to decrease.
- **18. Explain** Which has the greater amount of thermal energy, one liter of water at 50°C or two liters of water at 50°C?

- **19. Explain** whether or not the following statement is true: If the thermal energy of an object increases, the temperature of the object must also increase.
- **20. Predict** Suppose a beaker of water is heated from the top. Explain which is more likely to occur in the water—thermal energy transfer by conduction or convection.
- **21.** Classify Order the events that occur in the removal of thermal energy from an object by a refrigerator. Draw the complete cycle, from the placing of a warm object in the refrigerator to the changes in the coolant.

#### **Applying Math**

Use the table below to answer questions 22 to 24.

Specific Heat of Materials				
Material	Specific Heat (J/kg°C)			
Water	4,184			
Copper	385			
Silver	235			
Graphite	710			
Iron	450			

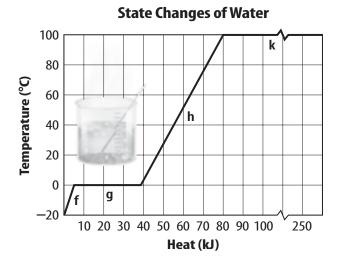
- **22.** Calculate Thermal Energy How much thermal energy is needed to raise the temperature of 4.0 kg of water from 25°C to 75°C?
- **23.** Calculate Temperature Change How does the temperature of 33.0 g of graphite change when it absorbs 350 J of thermal energy?
- **24.** Calculate Mass A certain mass of water gains 1,673 J of thermal energy when its temperature increases by 2.0°C. What is the mass of the water?

# Standardized Test Practice chapter

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### **Multiple Choice**

Use the graph below to answer questions 1 and 2.



- **1.** At which points on the graph is the average kinetic energy of the water molecules increasing?
  - A. F and G
  - B. G and K
  - C. F and H
  - D. H and K
- 2. At which points on the graph is the potential energy of the water molecules increasing, but the average kinetic energy is not?
  - A. F and G
  - B. G and K
  - C. F and H
  - D. H and K

#### Test-Taking Tip

Read Carefully Read all choices before answering the question.

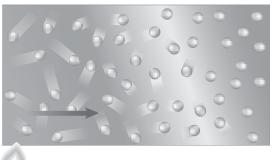
- **3.** Which is the term for the amount of energy required for 1 kg of a liquid at its boiling point to become a gas?
  - **A.** heat of vaporization
  - **B.** diffusion
  - **c.** heat of fusion
  - **D.** thermal energy

Use the table below to answer questions 4 and 5.

Material	Specific Heat [J/(kg °C)]	
Copper	385	
Gold	449	
Lead	129	
Tin	228	
Zinc	388	

- **4.** According to the table above, a 2-kg block of which of the following materials would require 898 J of heat to increase its temperature by 1°C?
  - A. gold
  - **B.** lead
  - C. tin
  - D. zinc
- **5.** Which of the following materials would require the most heat to raise a 5-kg sample of the material from 10°C to 50°C?
  - **A.** gold
  - B. lead
  - C. tin
  - D. zinc

#### Use the figure below to answer question 6.





- **6.** The illustration above shows the particles in a material being heated at one end. Thermal energy is transferred from the warmer part of the material to the cooler part. What heat transfer process is occurring in the material?
  - A. conduction
  - **B.** convection
  - **C.** radiation
  - **D.** entropy

#### **Gridded Response**

- **7.** The temperature of a 24.5-g block of aluminum decreases from 30.0°C to 21.5°C. If aluminum has a specific heat of 897 J/(kg °C), what is the change in thermal energy, measured in joules, of the block of aluminum?
- **8.** The difference between the boiling point and the freezing point of potassium is 695.72 K. What is this difference in degrees on the Celsius temperature scale?

#### Short Response

- **9.** Explain how the temperature and thermal energy of an object are related.
- **10.** What property of water makes it useful as a coolant?

#### **Extended Response**

Use the figure below to answer question 11.



- **11.** The figure shows a calorimeter that is used to measure the specific heat of materials.
  - **PART A** Explain why it is necessary to measure the temperature change of the water when using a calorimeter to measure the specific heat of a material.
  - **PART B** Explain why the calorimeter must be insulated from its surroundings.
- **12.** Explain how changes in a fluid's density enable convection currents to occur.

# chapter

# O

#### BIG (Idea

Waves transfer energy from place to place without transferring matter.

#### 10.1 The Nature of Waves

MAIN (Idea Waves move through matter as energy is transferred from particle to particle.

#### **10.2 Wave Properties**

MAIN (Idea Wave properties depend on the vibrations of the wave source and the material in which the wave moves.

# 10.3 The Behavior of Waves

MAIN (Idea Waves can change direction when they interact with matter.

# Hanging In

This surfer in Hawaii is surrounded by an ocean wave that forms a huge tube of water. But even sitting at your desk, you are also surrounded by waves. Everything you see or hear is brought to you by waves. Easy to see-like this ocean wave-or invisible, all waves carry energy.

#### **Science Journal**

Write down three things you already know about waves and one thing you would like to learn about waves.



# **Start-Up Activities**



#### How do waves transfer energy?

Light enters your eyes and sound strikes your ears, enabling you to sense the world around you. Light and sound are waves that transfer energy from one place to another. Do waves transfer anything else along with their energy? Does a wave transfer matter, too? In this activity, you'll observe one way that waves can transfer energy.

- 1. Complete the safety form.
- 2. Place your textbook flat on your desk. Line up four marbles on the groove at the edge of the textbook so that the marbles are touching each other.
- 3. Hold the first three marbles in place using three fingers of one hand.
- 4. Tap the first marble with a pen or pencil.
- 5. Observe the behavior of the fourth marble.
- **6. Think Critically** Write a paragraph explaining how the fourth marble reacted to the pen tap. Diagram how energy was transferred through the marbles.



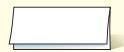
Preview this chapter's content and activities at

gpescience.com



Types of Waves Make the following Foldable to compare and contrast two types of waves.

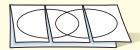
**STEP 1 Fold** one sheet of paper lengthwise.



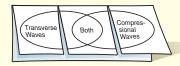
**STEP 2 Fold** into thirds.



STEP 3 **Unfold and draw** overlapping ovals. Cut the top sheet along the folds.



Label the ovals as shown.



Construct a Venn Diagram As you read this chapter, list properties and characteristics unique to transverse waves under the left tab, those unique to compressional waves under the right tab, and those common to both under the middle tab.

# **The Nature of Waves**

# **Reading Guide**

#### What You'll Learn

- Recognize that waves transfer energy but not matter.
- Define mechanical waves.
- Compare and contrast transverse waves and compressional waves.

# Why It's Important

You can see and hear the world around you because of the energy transferred by waves.

### Review Vocabulary

energy: the ability to do work

#### **New Vocabulary**

- wave
- medium
- transverse wave
- compressional wave

### What's in a wave?

A surfer bobs in the ocean waiting for the perfect wave, microwaves warm up your leftover pizza, and sound waves from your CD player bring music to your ears. Do these and other types of waves have anything in common with one another?

A wave is a repeating disturbance or movement that transfers energy through matter or space. For example, ocean waves disturb the water and transfer energy through it. During earthquakes, energy is transferred in powerful waves that travel through Earth. Light is a type of wave that can travel through empty space to transfer energy from one place to another, such as from the Sun to Earth.

**Figure 1** Falling pebbles transfer their kinetic energy to the particles of water in a pond, forming waves.



# **Waves and Energy**

Kerplop! A pebble falls into a pool of water and ripples form. As **Figure 1** shows, the pebble causes a disturbance that moves outward in the form of a wave. Because it is moving, the falling pebble has energy. As it splashes into the pool, the pebble transfers some of its energy to nearby water molecules, causing them to move. These molecules then pass the energy along to neighboring water molecules, which, in turn, transfer it to their neighbors. The energy moves farther and farther from the source of the disturbance. What you see is energy traveling in the form of a wave on the surface of the water.

Waves and Matter Imagine that you're in a boat on a lake. Approaching waves bump against your boat, but they don't carry it along with them as they pass. The boat does move up and down and maybe even a short distance back and forth because the waves transfer some of their energy to it. However, after the waves have moved on, the boat is still in nearly the same place. The waves don't even carry the water along with them. Only the energy transferred by the waves moves forward. All waves have this property—they transfer energy without transporting matter from place to place.

Reading Check What do waves transfer?

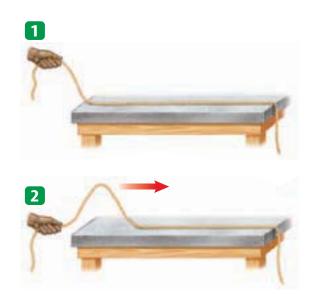
**Making Waves** A wave will travel only as long as it has energy to transfer. For example, when you drop a pebble into a puddle, the ripples soon die out and the surface of the water becomes still again.

Suppose you are holding a rope at one end, and you give it a shake. You would create a pulse that would travel along the rope to the other end, and then the rope would be still again, as **Figure 2** shows. Now suppose you shake your end of the rope up and down for a while. You would make a wave that would travel along the rope. When you stop shaking your hand up and down, the rope will be still again. It is the upand-down motion of your hand that creates the wave.

Anything that moves up and down or back and forth in a rhythmic way is vibrating. The vibrating movement of your hand at the end of the rope created the wave. In fact, all waves are produced by something that vibrates.

#### **Mechanical Waves**

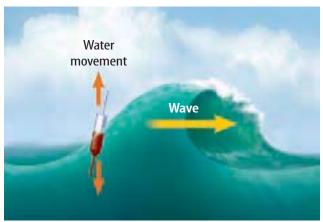
Sound waves travel through the air to reach your ears. Ocean waves move through water to reach the shore. In both cases, the matter the waves travel through is called a **medium**. A medium can be a solid, a liquid, a gas, or a combination of these. For sound waves, the medium is air, and for ocean waves, the medium is water. Not all waves need a medium. Some waves, such as light and radio waves, can travel through space. Waves that can travel only through matter are called mechanical waves. The two types of mechanical waves are transverse waves and compressional waves.







**Figure 2** A wave will exist only as long as it has energy to transfer. **Explain** what happened to the energy that was transferred by the wave in this rope.



moves vertically up and down.

transverse of from you to and down.

Figure 3 A water wave

travels horizontally as the water

transverse of from you to and down.

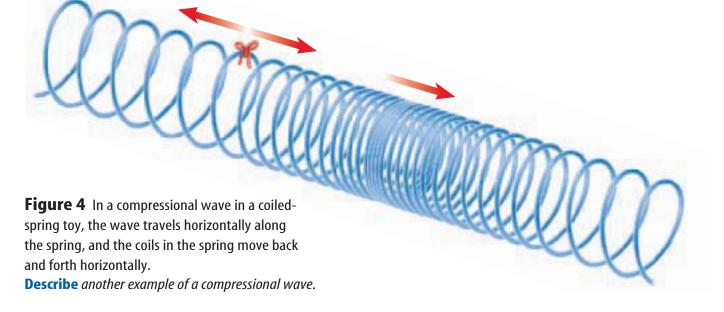
Compressional Waves

the medium moves back ar

**Transverse Waves** In a **transverse wave**, matter in the medium moves back and forth at right angles to the direction that the wave travels. For example, **Figure 3** shows how a wave in the ocean moves horizontally, but the water that the wave passes through moves up and down. When you shake one end of a rope while your friend holds the other end, you are making transverse waves. The wave and its energy travel from you to your friend as the rope moves up and down

Compressional Waves In a compressional wave, matter in the medium moves back and forth along the same direction that the wave travels. You can model compressional waves with a coiled-spring toy, as shown in **Figure 4.** Squeeze several coils together at one end of the spring. Then let go of the coils, still holding onto coils at both ends of the spring. A wave will travel along the spring. As the wave moves, it looks as if the whole spring is moving toward one end. Suppose you watched the coil with yarn tied to it, as in **Figure 4.** You would see that the yarn moves back and forth as the wave passes, and then it stops moving after the wave has passed. The wave transfers energy, but not matter, forward along the spring. Compressional waves also are called longitudinal waves.

**Sound Waves** Sound waves are compressional waves. When a noise is made, such as when a locker door slams shut and vibrates, nearby air molecules are pushed together by the vibrations. The air molecules are squeezed together like the coils in a coiled-spring toy are when you make a compressional wave with it. The compressions travel through the air to make a wave.



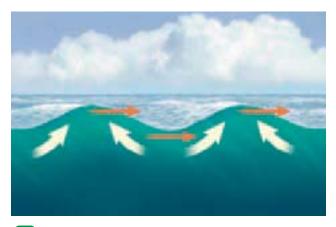
Sound in Other Materials Sound waves also can travel through other mediums, such as water and wood. Particles in these mediums also are pushed together and move apart as the sound waves travel through them. When a sound wave reaches your ear, it causes your eardrum to vibrate. Your inner ear then sends signals to your brain, and your brain interprets the signals as sound.

Reading Checke How do sound waves travel in solids?

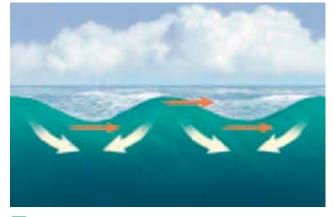
**Water Waves** Water waves are not purely transverse waves. The water moves up and down as the waves go by. However, the water also moves a short distance back and forth along the direction the wave is moving. This movement happens because the low part of the wave can be formed only by pushing water forward or backward toward the high part of the wave, as in **Figure 5A.** Then, as the wave passes, the water that was pushed aside moves back to its initial position, as in **Figure 5B.** In fact, if you looked closely, you would see that the combination of this up-and-down and back-and-forth motion causes water to move in circles. Anything floating on the surface of the water absorbs some of the waves' energy and bobs in a circular motion.

Ocean waves are formed most often by wind blowing across the ocean surface. As the wind blows faster and slower, the changing wind speed is like a vibration. The size of the waves that are formed depends on the wind speed, the distance over which the wind blows, and how long the wind blows. Figure 6 on the next page shows how ocean waves are formed.

**Figure 5** A water wave causes water to move back and forth, as well as up and down. Water is pushed back and forth to form the crests and troughs.



A The low point of a water wave is formed when water is pushed aside and up to the high point of the wave.

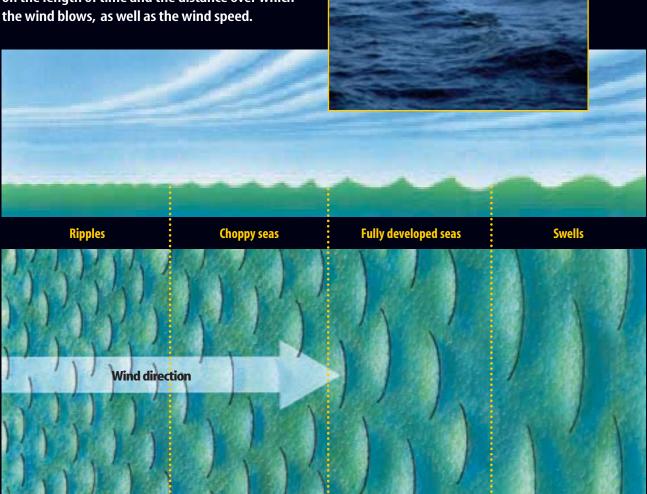


B The water that is pushed aside returns to its initial position.

# NATIONAL GEOGRAPHIC VISUALIZING FORMATION OF OCEAN WAVES

#### Figure 6

hen wind blows across an ocean, friction between the moving air and the water causes the water to move. As a result, energy is transferred from the wind to the surface of the water. The waves that are produced depend on the length of time and the distance over which the wind blows, as well as the wind speed.

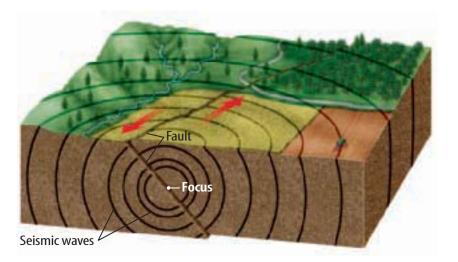


▲ Wind causes ripples to form on the surface of the water. As ripples form, they provide an even larger surface area for the wind to strike, and the ripples increase in size.

Waves that are higher and have longer wavelengths grow faster as the wind continues to blow, but the steepest waves break up, forming whitecaps. The surface is said to be choppy.

The shortest-wavelength waves break up, while the longest-wavelength waves continue to grow. When these waves have reached their maximum height, they form fully developed seas.

After the wind dies down, the waves lose energy and become lower and smoother. These smooth, longwavelength ocean waves are called swells.



**Figure 7** When Earth's crust shifts or breaks, the energy that is released is transmitted outward, causing an earthquake.

**Explain** why earthquakes are mechanical waves.

**Seismic Waves** A guitar string makes a sound when it breaks. The string vibrates

for a short time after it breaks and produces sound waves. In a similar way, forces in Earth's crust can cause regions of the crust to shift, bend, or even break. The breaking crust vibrates, creating seismic waves that transfer energy outward, as shown in **Figure 7.** Seismic waves are a combination of compressional and transverse waves. They can travel through Earth and along Earth's surface. When objects on Earth's surface absorb some of the energy transferred by seismic waves, they move and shake. The more the crust moves during an earthquake, the more energy is released.



#### **Topic: Seismic Waves**

Visit gpescience.com for Web links to information about seismic waves.

**Activity** Write a summary of how seismic waves are used to map Earth's interior.

# section

#### **Summary**

#### **Waves and Energy**

- A wave is a repeating disturbance or movement that transfers energy through matter or space.
- Waves transfer energy without transporting matter.
- Waves are produced by something that is vibrating.

#### **Mechanical Waves**

- Mechanical waves must travel in matter.
- Mechanical waves can be transverse waves or compressional waves.
- In a transverse wave, matter in the medium moves at right angles to the wave motion.
- In a compressional wave, matter in the medium moves back and forth along the direction of the wave motion.

#### Self Check

1. Compare and contrast a transverse wave and a compressional wave. Give an example of each type.

review

- **2. Describe** the motion of a buoy when a water wave passes. Does it move the buoy forward?
- 3. Explain how you could model a compressional wave using a coiled-spring toy.
- 4. List the characteristics of a mechanical wave.
- **5. Think Critically** Why do boats need anchors if ocean waves do not carry matter forward?

#### **Applying Math**

**6. Calculate Time** The average speed of sound in water is 1,500 m/s. How long would it take a sound wave to travel 9,000 m?

# **Wave Properties**

## **Reading Guide**

# What You'll Learn

- Define wavelength, frequency, period, and amplitude.
- Describe the relationship between frequency and wavelength.
- Explain how a wave's energy and amplitude are related.
- Calculate wave speed.

# Why It's Important

Waves with different properties can be used in different ways.

#### Review Vocabulary

**vibration:** a back and forth movement

#### **New Vocabulary**

- crest
- frequency
- trough
- period
- rarefaction
- amplitude
- wavelength

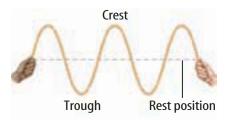
#### The Parts of a Wave

What makes sound waves, water waves, and seismic waves different from each other? Waves can differ in how much energy they transfer and in how fast they travel. Waves also have other characteristics that make them different from each other.

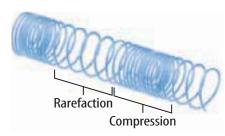
Suppose you shake the end of a rope and make a transverse wave. The transverse wave in **Figure 8** has alternating high points, called **crests**, and low points, called **troughs**.

On the other hand, a compressional wave has no crests and troughs. When a compressional wave passes through a medium, it creates regions where the medium becomes crowded together and more dense, as in **Figure 8**. These regions are compressions. When you make compressional waves in a coiled spring, the compressions are regions where the coils are close together. **Figure 8** also shows that the coils in the regions next to a compression are spread apart, or less dense. These less-dense regions of a compressional wave are called **rarefactions**.

**Figure 8** Transverse and compressional waves have different features that travel through a medium and form the wave.

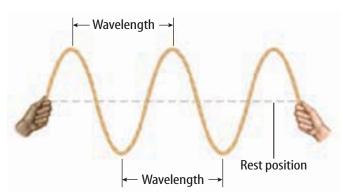


A transverse wave is made of crests and troughs that travel through the medium.

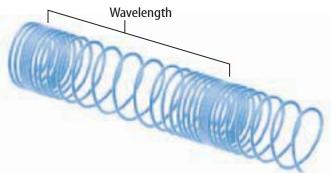


A compressional wave is made of compressions and rarefactions that travel through the medium.

**Figure 9** One wavelength starts at any point on a wave and ends at the nearest point just like it.



For transverse waves, a wavelength can be measured from crest to crest or trough to trough.



The wavelength of a compressional wave can be measured from compression to compression or from rarefaction to rarefaction.

# **Wavelength**

Waves also have a property called wavelength. A **wavelength** is the distance between one point on a wave and the nearest point just like it. **Figure 9** shows that for transverse waves, the wavelength is the distance from crest to crest or trough to trough.

A wavelength in a compressional wave is the distance between two neighboring compressions or two neighboring rarefactions, as shown in **Figure 9.** You can measure from the start of one compression to the start of the next compression or from the start of one rarefaction to the start of the next rarefaction. The wavelengths of sound waves that you can hear range from a few centimeters for the highest-pitched sounds to about 15 m for the deepest sounds.



How is wavelength measured in transverse and compressional waves?

# **Frequency and Period**

When you tune your radio to a station, you are choosing radio waves of a certain frequency. The **frequency** of a wave is the number of wavelengths that pass a fixed point each second. You can find the frequency of a transverse wave by counting the number of crests or troughs that pass by a point each second. The frequency of a compressional wave is the number of compressions or rarefactions that pass a point every second. Frequency is expressed in hertz (Hz). A frequency of 1 Hz means that one wavelength passes by in 1 s. In SI units, 1 Hz is the same as 1/s. The **period** of a wave is the amount of time it takes one wavelength to pass a point. As the frequency of a wave increases, the period decreases. Periods are measured in units of seconds.



#### **Observing Wavelength**

#### Procedure 🗪 😘

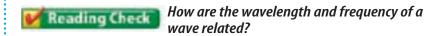
- **1.** Complete the safety form.
- 2. Fill a pie plate or other wide pan with water about 2 cm deep.
- Lightly tap your finger once per second on the surface of the water and observe the spacing of the water waves.
- Increase the rate of your tapping, and observe the spacing of the water waves.

#### **Analysis**

- 1. How is the spacing of the water waves related to their wavelength?
- 2. How does the spacing of the water waves change when the rate of tapping increases?

**Wavelength Is Related to Frequency** If you make transverse waves with a rope, you increase the frequency by moving the rope up and down faster. Moving the rope faster also makes the wavelength shorter. This relationship is always true: as frequency increases, wavelength decreases. **Figure 10** compares the wavelengths and frequencies of two different waves.

The frequency of a wave is always equal to the rate of vibration of the source that creates it. If you move the rope up, down, and back up in 1 s, the frequency of the wave you generate is 1 Hz. If you move the rope up, down, and back up five times in 1 s, the resulting wave has a frequency of 5 Hz.

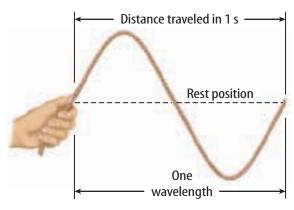


# **Wave Speed**

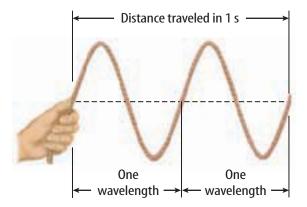
You're at a large stadium watching a baseball game, but you're high up in the bleachers, far from the action. The batter swings and you see the ball rise. An instant later, you hear the crack of the bat hitting the ball. You see the impact before you hear it because light waves travel much faster than sound waves. Therefore, the light waves reflected from the flying ball reach your eyes before the sound waves created by the crack of the bat reach your ears.

The speed of a wave depends on the medium it is traveling through. Sound waves usually travel faster in liquids and solids than they do in gases. However, light waves travel more slowly in liquids and solids than they do in gases or in empty space. Also, sound waves usually travel faster in a material when the temperature of the material is increased. For example, sound waves travel faster in air at 20°C than in air at 0°C.

**Figure 10** The wavelength of a wave decreases as the frequency increases.



The rope is moved down, up, and down again one time in 1 s. One wavelength is created on the rope.



The rope is shaken down, up, and down again twice in 1 s. Two wavelengths are created on the rope.

**Calculating Wave Speed** You can calculate the speed of a wave, represented by v, by multiplying its frequency times its wavelength. Wavelength is represented by the Greek letter  $lambda(\lambda)$ , and frequency is represented by f.

#### **Wave Speed Equation**

speed (in m/s) = frequency (in Hz) 
$$\times$$
 wavelength (in m)  
 $v = f \lambda$ 

Why does multiplying the frequency unit Hz by the distance unit m give the unit for speed, m/s? Recall that the SI unit Hz is the same as 1/s. Multiplying  $m \times Hz$  equals  $m \times 1/s$ , which equals m/s.



#### **Deadly Ocean Waves**

Tsunamis can cause serious damage when they hit land. These waves can measure up to 30 m tall and can travel faster than 700 km/h. Research which areas of the world are most vulnerable to tsunamis. Describe the effects of a tsunami that has occurred in these areas.

#### **Applying Math**

#### **Solve a Simple Equation**

**THE SPEED OF SOUND** What is the speed of a sound wave that has a wavelength of 2.00 m and a frequency of 170.5 Hz?

#### **IDENTIFY** known values and the unknown value

Identify the known values:

wavelength of 2.0 m 
$$\lambda = 2.00 \text{ m}$$

frequency of 170.5 Hz 
$$f = 170.5 \text{ Hz}$$

Identify the unknown value:

the speed of a sound wave 
$$v = m / s$$

#### **SOLVE** the problem

Substitute the known values  $\lambda = 2.00$  m and f = 170.5 Hz into the wave speed equation:

$$v = f\lambda = (170.5 \text{ Hz}) (2.00 \text{ m}) = 341 \text{ m/s}$$

#### CHECK the answer

Does your answer seem reasonable? Check your answer by dividing the wave speed you calculated by the wavelength given in the problem. The result should be the frequency given in the problem.

#### **Practice Problems**

- **1.** A wave traveling in water has a frequency of 500.0 Hz and a wavelength of 3.0 m. What is the speed of the wave?
- **2.** The lowest-pitched sounds humans can hear have a frequency of 20.0 Hz. What is the wavelength of these sound waves if their wave speed is 340.0 m/s?
- **3.** The highest-pitched sound humans can hear have a wavelength of 0.017 m in air. What is the frequency of these sound waves if their wave speed is 340.0 m/s?

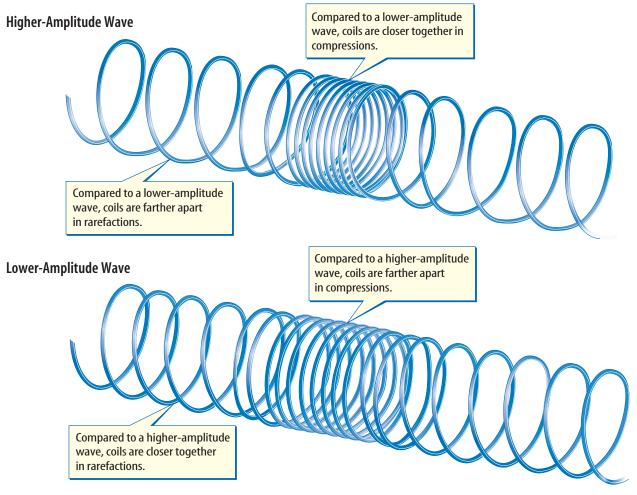
For more practice problems go to page 879, and visit Math Practice at gpescience.com.

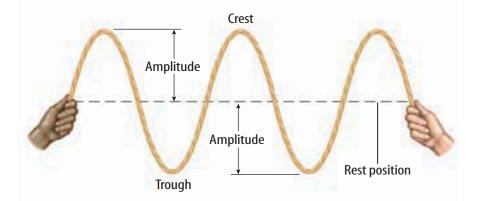
# **Amplitude and Energy**

Why do some earthquakes cause terrible damage, while others are hardly felt? This is because the amount of energy a wave transfers can vary. **Amplitude** is related to the energy transferred by a wave. The greater the wave's amplitude, the more energy the wave transfers. Amplitude is measured differently for compressional and transverse waves.

**Amplitude of Compressional Waves** The amplitude of a compressional wave is related to how tightly the medium is pushed together at the compressions. The denser the medium is at the compressions, the larger its amplitude is and the more energy the wave transfers. For example, it takes more energy to push the coils in a coiled-spring toy tightly together than to barely move them. The closer the coils are in a compression, the farther apart they are in a rarefaction. So, the less dense the medium is at the rarefactions, the more energy the wave transfers. **Figure 11** shows compressional waves with different amplitudes.

**Figure 11** The amplitude of a compressional wave depends on the density of the medium in the compressions and rarefactions.





**Figure 12** The amplitude of a transverse wave is the distance between a crest or a trough and the position of the medium at rest. **Describe** how you could create waves with different amplitudes in a piece of rope.

**Amplitude of Transverse Waves** If you've ever been knocked over by an ocean wave, you know that the higher the wave, the more energy it transfers. Remember that the amplitude of a wave increases as the energy transferred by the wave increases. So a tall ocean wave has a greater amplitude than a short ocean wave does. The amplitude of any transverse wave is the distance from the crest or trough of the wave to the rest position of the medium, as shown in **Figure 12.** 

# section (2) review

#### Summary

#### The Parts of a Wave

- Transverse waves have repeating high points called crests and low points called troughs.
- Compressional waves have repeating highdensity regions called compressions, and low-density regions called rarefactions.

#### Wavelength, Frequency, and Period

- Wavelength is the distance between a point on a wave and the nearest point just like it.
- A wave's frequency is the number of wavelengths passing a fixed point each second.
- A wave's period is the amount of time it takes one wavelength to pass a fixed point.

#### **Wave Speed and Amplitude**

- The speed of a wave depends on the material it is traveling in, and on the temperature.
- The speed of a wave is the product of its frequency and its wavelength:

$$v = f \lambda$$

• As the amplitude of a wave increases, the energy transferred by the wave increases.

#### **Self Check**

- Describe the difference between a compressional wave with a large amplitude and one with a small amplitude.
- **2. Describe** how the wavelength of a wave changes when the wave slows down but its frequency doesn't change.
- **3. Explain** how the frequency of a wave changes when the period of the wave increases.
- **4. Form a hypothesis** to explain why a sound wave travels faster in a solid than in a gas.
- 5. Think Critically You make a transverse wave by shaking the end of a long rope up and down. Explain how you would shake the end of the rope to make the wavelength shorter. How would you shake the end of the rope to increase the energy transferred by the wave?

#### **Applying Math**

- **6. Calculate** the frequency of a water wave that has a wavelength of 0.5 m and a speed of 4.0 m/s.
- 7. Calculate Wavelength An FM radio station broadcasts radio waves with a frequency of 100,000,000 Hz. What is the wavelength of these radio waves if they travel at a speed of 300,000 km/s?



# Wave Speed and TenSion

Before playing her violin, a violinist must adjust the tension, or the amount of force pulling on each string, to tune the violin.

# Real-World Problem

How does the tension in a material affect the waves traveling in the material?

#### Goal

■ **Determine** the relationship between tension and wave speed.

#### **Materials**

coiled-spring toy stopwatch

meterstick

#### **Safety Precautions**



# Procedure

- 1. Complete the safety form.
- **2.** Attach one end of the spring to a chair leg so that the spring rests on a smooth floor.
- **3.** Stretch the spring along the floor to a length of 1 m.
- **4.** Make a compressional wave by squeezing together several coils and then releasing them.
- 5. Have your partner time how long the wave takes to travel two or three lengths of the spring. Record the time in your data table. Record the distance the wave traveled in your data table.
- **6.** Repeat steps 4 and 5 two more times for waves 2 and 3.
- **7.** Stretch the spring to a length of 1.5 m.
- **8.** Repeat steps 4 and 5 for waves 4, 5, and 6.

Data Table				
	Distance (m)	Wave Time (s)	Wave Speed (m/s)	
Wave 1				
Wave 2				
Wave 3	Do n	ot write in this	book.	
Wave 4				
Wave 5				
Wave 6				

# Analyze Your Data

 Calculate the wave speed for each wave using the formula:

speed = distance/time

- **2.** Calculate the average speed of the waves on the spring with a length of 1.0 m by adding the measured wave speeds and dividing by 3.
- **3.** Calculate the average speed of the waves on the spring with a length of 1.5 m.

# Conclude and Apply

- **1.** How did the tension in the spring change as the length of the spring increased?
- **2.** How did the wave speed depend on the tension? How could you make the waves travel even faster? Test your prediction.



**Compare** your results with those of other students in your class. Discuss why results might be different.

# The Behavior of Waves

# **Reading Guide**

## What You'll Learn

- State the law of reflection.
- Explain why waves change direction when they travel from one material to another.
- Compare and contrast refraction and diffraction.
- Describe how waves interfere with each other.

# Why It's Important

You can hear an echo, see shadows, and check your reflection in a mirror because of how waves behave.

#### Review Vocabulary

**perpendicular:** a line that forms a 90-degree angle with another line

#### **New Vocabulary**

- refraction
- diffraction
- interference
- standing wave
- resonance

## Reflection

If you are one of the last people to leave your school building at the end of the day, you'll probably find the hallways quiet and empty. When you close your locker door, the sound echoes down the empty hall. Your footsteps also make a hollow sound. Thinking you're alone, you may be startled by your own reflection in a classroom window. The echoes and your image looking back at you from the window are caused by wave reflection.

Reflection occurs when a wave strikes an object and bounces off it. All types of waves—including sound, water, and light waves—can be reflected. How does the reflection of light allow the boy in **Figure 13** to see himself in the mirror? It happens in two steps. First, light strikes his face and bounces off. Then, the light reflected off his face strikes the mirror and is reflected into his eyes.

**Echoes** A similar thing happens to sound waves when your footsteps echo. Sound waves form when your foot hits the floor and the waves travel through the air to both your ears and other objects. Sometimes, when the sound waves hit another object, they reflect off it and come back to you. Your ears hear the sound again, a few seconds after you first heard your footstep.

Bats and dolphins use echoes to learn about their surroundings. A dolphin makes a clicking sound and listens to the echoes. These echoes enable the dolphin to locate nearby objects.

**Figure 13** The light that strikes the boy's face is reflected into the mirror. The light then reflects off the mirror into his eyes.

**List** examples of waves that can be reflected.





**Figure 14** A flashlight beam is made of light waves. When any wave is reflected, the angle of incidence, i, equals the angle of reflection, r.



**The Law of Reflection** Look at the two light beams in **Figure 14.** The beam striking the mirror is called the incident beam. The beam that bounces off the mirror is called the reflected beam. The line drawn perpendicular to the surface of the mirror is called the normal. The angle formed by the incident beam and the normal is the angle of incidence, labeled i. The angle formed by the reflected beam and the normal is the angle of reflection, labeled r. According to the law of reflection, the angle of incidence is equal to the angle of reflection. All reflected waves obey this law. Objects that bounce from a surface sometimes behave like waves that are reflected from a surface. For example, suppose you throw a bounce pass while playing basketball. The angle between the ball's direction and the normal to the floor is the same before and after it bounces.

## Refraction

Do you notice anything unusual in **Figure 15?** The pencil looks as if it is broken into two pieces. But if you pulled the pencil out of the water, you would see that it is unbroken. This illusion is caused by refraction. How does it work?

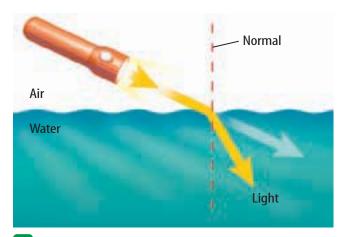
Remember that a wave's speed depends on the medium it is moving through. When a wave passes from one medium to another—such as when a light wave passes from air to water it changes speed. If the wave is traveling at an angle when it passes from one medium to another, it changes direction, or bends, as it changes speed. Refraction is the bending of a wave caused by a change in its speed as it moves from one medium to another. The greater the change in speed is, the more the wave bends.

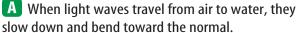


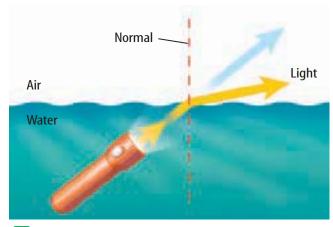
Figure 16A on the next page shows what happens when a wave passes into a material in which it slows down. The wave is refracted (bent) toward the normal. Figure 16B shows what happens when a wave passes into a medium in which it speeds up. Then the wave is refracted away from the normal.

**Figure 15** The pencil looks like it is broken at the surface of the water because of refraction.

**Figure 16** Light waves travel more slowly in water than in air. This causes light waves to change direction when they move from water to air or air to water. **Predict** how the beam would bend if the speed were the same in both air and water.

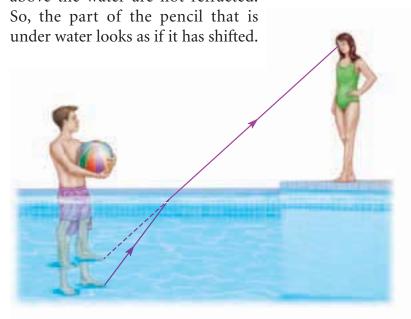






B When light waves travel from water to air, they speed up and bend away from the normal.

Refraction of Light in Water You may have noticed that objects that are under water seem closer to the surface than they really are. **Figure 17** shows how refraction causes this illusion. In the figure, the light waves reflected from the boy's foot are refracted away from the normal and enter your eyes. However, your brain assumes that all light waves have traveled in a straight line. The light waves that enter your eyes seem to have come from a foot that was higher in the water. This is also why the pencil in **Figure 15** seems broken. The light waves coming from the part of the pencil that is under water are refracted, but your brain interprets them as if they have traveled in a straight line. However, the light waves coming from the part of the pencil above the water are not refracted.



**Figure 17** Light waves from the boy's foot bend away from the normal as they pass from water to air. This makes his foot look closer to the surface than it really is. **Infer** whether the boy's knee would seem closer to the surface than it is.

Figure 18 Diffraction causes ocean waves to change direction as they pass a group of islands.



## **Diffraction**

When waves strike an object, several things can happen. Some of the wave's energy can be absorbed by the object. The waves can also be reflected. If the object is transparent, light waves can be refracted as they pass through it. Sometimes, the waves may be both reflected and refracted. If you look into a glass window, sometimes you can see your reflection in the window, as well as objects behind it.

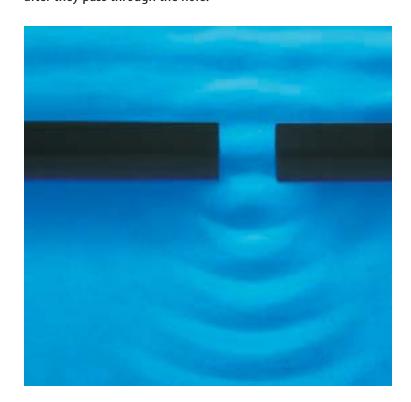
Waves also can behave another way when they strike an object. The waves can bend around the object. Figure 18 shows

> how ocean waves change direction and bend after they strike an island. **Diffraction** occurs when an object causes a wave to change direction and bend around it. Diffraction and refraction both cause waves to bend. The difference is that refraction occurs when waves pass through an object, while diffraction occurs when waves pass around an object.

How do diffraction Reading Check and refraction differ?

Waves also can be diffracted when they pass through a narrow opening, as shown in **Figure 19.** After they pass through the opening, the waves spread out. In this case, the waves are bending around the corners of the opening.

Figure 19 When water waves pass through a small opening in a barrier, they diffract and spread out after they pass through the hole.



**Diffraction and Wavelength** How much does a wave bend when it strikes an object or an opening? The amount of diffraction that occurs depends on how big the obstacle or opening is compared to the wavelength, as shown in Figure 20. When an obstacle is smaller than the wavelength, the waves bend around it. But if the obstacle is larger than the wavelength, the waves do not diffract as much. In fact, if the obstacle is much larger than the wavelength, almost no diffraction occurs. The obstacle casts a shadow because almost no waves bend around it.

**Hearing Around Corners** For example, suppose that you're walking down a hallway and hear sounds coming from the lunchroom before you reach the open lunchroom door. However, you can't see into the room until you reach the doorway. Why can you hear the sound waves but not see the light waves while you're still in the hallway? The wavelengths of sound waves are similar in size to a door opening. Sound waves diffract around the door and spread out down the hallway. Light waves have a much shorter wavelength. They are hardly diffracted at all by the door. This is why you can't see into the room until you get close to the door.

**Diffraction of Radio Waves** Diffraction also affects your radio's reception. AM radio waves have longer wavelengths than FM radio waves do. Because of their longer wavelengths, AM radio waves diffract around obstacles such as buildings and mountains. The FM waves with their short wavelengths do not diffract as much. As a result, AM radio reception is often better than FM reception around tall buildings and natural barriers such as hills.

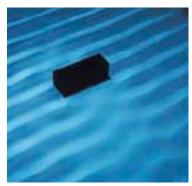


#### **Topic: Diffraction**

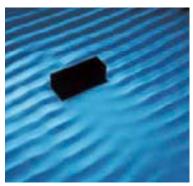
Visit **gpescience.com** for Web links to information about diffraction.

**Activity** Research the wave lengths of several types of waves. For each wave type, give an example of an object that could cause diffraction to occur.

**Figure 20** The diffraction of waves around an obstacle depends on the wavelength and the size of the obstacle.



More diffraction occurs when the wavelength is the same size as the obstacle.



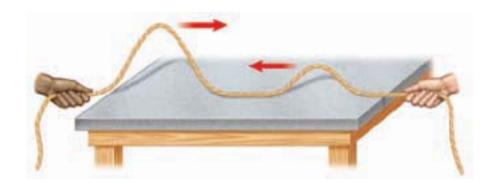
Less diffraction occurs when the wavelength is smaller than the obstacle.

## Interference

Suppose two waves are traveling toward each other on a long rope, as in **Figure 21A.** What will happen when the two waves meet? If you did this experiment, you would find that the two waves pass right through each other, and each one continues to travel in its original direction, as shown in Figure 21B and **Figure 21C.** If you look closely at the waves when they meet each other in **Figure 21B**, you will see a wave that looks different from either of the two original waves. When the two waves arrive at the same place at the same time, they combine to form a new wave. When two or more waves overlap and combine to form a new wave, the process is called interference. This new wave exists only while the two original waves continue to overlap. The two ways that the waves can combine are called constructive interference and destructive interference.

**Figure 21** Interference occurs while two waves are overlapping. Then the waves combine to form a new wave. Two waves traveling on a rope can interfere with each other.

A Two waves move toward each other on a rope.

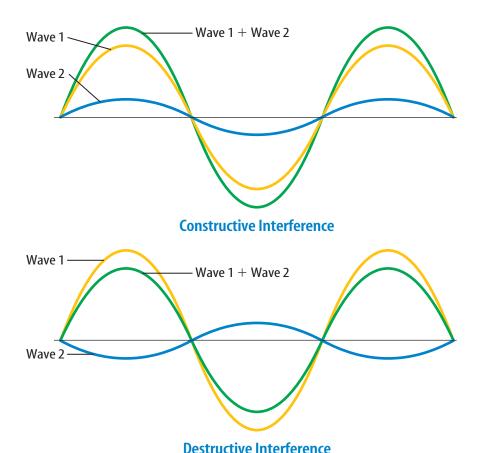


B As the waves overlap, they interfere to form a new wave. **Identify** What is the amplitude of the new wave?



While the two waves overlap, they continue to move right through each other. Afterward, they continue moving unchanged, as if they had never met.





**Constructive Interference** In constructive interference, shown in **Figure 22A**, the waves add together. This happens when the crests of two or more transverse waves arrive at the same place at the same time and overlap. The amplitude of the new wave that forms is equal to the sum of the amplitudes of the original waves. Constructive interference also occurs when the compressions of different compressional waves overlap. If the waves are sound waves, for example, constructive interference produces a louder sound. Waves undergoing constructive interference are said to be in phase.

**Destructive Interference** In destructive interference, the waves subtract from each other as they overlap. This happens when the crests of one transverse wave meet the troughs of another transverse wave, as shown in **Figure 22B.** The amplitude of the new wave is the difference between the amplitudes of the waves that overlapped. With compressional waves, destructive interference occurs when the compression of one wave overlaps with the rarefaction of another wave. The compressions and rarefactions combine and form a wave with reduced amplitude. When destructive interference happens with sound waves, it causes a decrease in loudness. Waves undergoing destructive interference are said to be out of phase.

A If Wave 1 and Wave 2 overlap, they constructively interfere and form the green wave. Wave 1 and Wave 2 are in phase.

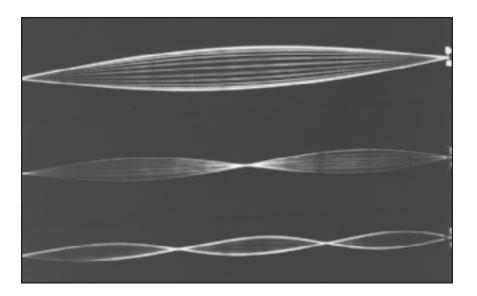
B If Wave 1 and Wave 2 overlap, they destructively interfere and form the green wave. Wave 1 and Wave 2 are out of phase.

**Figure 22** When waves interfere with each other, constructive and destructive interference can occur. **Infer** how the energy transferred by each wave changes when interference occurs.



Noise Damage People who are exposed to constant loud noises, such as those made by airplane engines, can suffer hearing damage. Special ear protectors have been developed that use destructive interference to cancel damaging noise. With a classmate, list all the jobs you can think of that require ear protectors.

Figure 23 Standing waves form a wave pattern that seems to stay in the same place. **Explain** how nodes form in a standing wave.



## **Standing Waves**

When you make transverse waves with a rope, you might shake one end while your friend holds the other end still. What would happen if you both shook the rope continuously to create identical waves moving toward each other? As the two waves travel in opposite directions down the rope, they continually pass through each other. Interference takes place as the waves from each end overlap along the rope. At any point where a crest meets a crest, a new wave with a larger amplitude forms. However, at points where crests meet troughs, the waves cancel each other and no motion occurs.

The interference of the two identical waves makes the rope vibrate in a special way, as shown in **Figure 23.** The waves create a pattern of crests and troughs that do not seem to be moving. Because the wave pattern stays in one place, it is called a standing wave. A standing wave is a special type of wave pattern that forms when waves equal in wavelength and amplitude, but traveling in opposite directions, continuously interfere with each other. The places where the two waves always cancel are called nodes. The nodes always stay in the same place on the rope. Meanwhile, the wave pattern vibrates between the nodes.

**Standing Waves in Music** When the string of a violin is played with a bow, it vibrates and creates standing waves. The standing waves in the string help produce a rich, musical tone. Other instruments also rely on standing waves to produce music. Some instruments, such as flutes, create standing waves in a column of air. In other instruments, such as drums, a tightly stretched piece of material vibrates in a special way to create standing waves. As the material in a drum vibrates, nodes are created on the surface of the drum.

## Resonance

You might have noticed that bells of different sizes and shapes create different notes. When you strike a bell, the bell vibrates at certain frequencies called the natural frequencies. All objects have their own natural frequencies of vibration, which depend on the object's size, shape, and the material it is made from.

There is another way to make something vibrate at its natural frequencies. Suppose you have a tuning fork that has a single natural frequency of 440 Hz. Imagine that a sound wave of the same frequency strikes the tuning fork. Because the sound wave has the same frequency as the natural frequency of the tuning fork, the tuning fork will vibrate. The process by which an object is made to vibrate by absorbing energy at its natural frequencies is called **resonance**.

Sometimes, resonance can cause an object to absorb a large amount of energy. Recall that the amplitude of a wave increases as the energy it transfers increases. In the same way, an object vibrates more strongly as it continues to absorb energy at its natural frequencies. If enough energy is absorbed, the object can vibrate so strongly that it breaks apart.



#### **Experimenting with** Resonance

#### Procedure

- 1. Complete the safety form.
- 2. Strike a tuning fork with a mallet.
- 3. Hold the vibrating tuning fork 1 cm from a second tuning fork that has the same frequency.
- **4.** Strike the tuning fork again. Hold it 1 cm from a third tuning fork that has a different frequency.

#### **Analysis**

How did the vibrating tuning fork affect the other tuning forks? Explain.

## section

## review

## **Summary**

#### **Reflection and Refraction**

- When reflection of a wave occurs, the angle of incidence equals the angle of reflection.
- Refraction occurs when a wave changes direction as it moves from one medium to another.

#### **Diffraction**

- Diffraction occurs when a wave changes direction by bending around an obstacle.
- The effects of diffraction are greatest when the wavelength is nearly the obstacle's size.

#### Interference and Resonance

- Interference occurs when two or more waves overlap and form a new wave.
- Interference between two waves with the same wavelength and amplitude, but moving in opposite directions, produces a standing wave.
- Resonance occurs when an object is made to vibrate by absorbing energy from vibrations at its natural frequencies.

#### **Self Check**

- 1. Compare the loudness of sound waves that are in phase when they interfere with the loudness of sound waves that are out of phase when they interfere.
- 2. Describe how the reflection of light waves enables you to see your image in a mirror.
- 3. **Describe** the energy transformations that occur when one tuning fork makes another tuning fork resonate.
- 4. Think Critically Suppose the speed of light were greater in water than in air. Draw a diagram to show whether an object under water would seem deeper or closer to the surface than it really is.

## **Applying Math**

- **5. Use Percentages** You aim a flashlight at a window. The radiant energy in the reflected beam is two-fifths of the energy in the incident beam. What percentage of the incident beam energy passed through the window?
- 6. Calculate Angle of Incidence The angle between a flashlight beam that strikes a mirror and the reflected beam is 80°. What is the angle of incidence?



# Measuriñg Wave Properties

#### Goals

- Measure the speed of a transverse wave.
- Create waves with different amplitudes.
- Measure the wavelength of a transverse wave.

#### **Materials**

long spring, rope, or hose meterstick stopwatch

#### **Safety Precautions**



## 🧶 Real-World Problem

Some waves travel through space; others pass through a medium such as air, water, or earth. Each wave has a wavelength, speed, frequency, and amplitude. How can the speed of a wave be measured? How can the wavelength be determined from the frequency?

## Procedure

- 1. Complete the safety form before you begin.
- 2. With a partner, stretch your spring across an open floor and measure the length of the spring. Record this measurement in the data table. Make sure the spring is stretched to the same length for each step.
- **3.** Have your partner hold one end of the spring. Create a single wave pulse by shaking the other end of the spring back and forth.
- **4.** Have a third person use a stopwatch to measure the time needed for the pulse to travel the length of the spring. Record this measurement in the *Wave Time* column of your data table.
- 5. Repeat steps 3 and 4 two more times.
- **6. Calculate** the speed of waves 1, 2, and 3 in your data table by using the formula speed = distance/time. Average the speeds of waves 1, 2, and 3 to find the speed of waves on your spring.
- **7. Create** a wave with several wavelengths. You make one wavelength when your hand moves left, right, and left again. Count the

number of wavelengths that you generate in 10 s. Record this measurement for wave 4 in the *Wavelength Count* column in your data table.

**8. Repeat** step 7 two more times. Each time, create a wave with a different wavelength by shaking the spring faster or slower.



## Using Scientific Methods

## 🧶 Analyze Your Data

- **1. Calculate** the frequency of waves 4, 5, and 6 by dividing the number of wavelengths by 10 s.
- Calculate the wavelength of waves 4, 5, and 6 using the formula wavelength = wave speed/frequency.
   Use the average speed calculated in step 5 for the wave speed.

Wave Property Measurement							
	Spring Length	Wave Time	Wave Speed				
Wave 1							
Wave 2							
Wave 3	Do not write in this book.						
	Wavelength Count	Frequency	Wavelength				
Wave 4							
Wave 5							
Wave 6							

## Conclude and Apply

- **1.** Was the wave speed different for the three different pulses you created? Why or why not?
- **2.** Why would you average the speeds of the three different pulses to calculate the speed of waves on your spring?
- 3. How did the wavelength of the waves you created depend on the frequency of the waves?



Ask your teacher to set up a contest between the groups in your class. Have each group compete to determine who can create waves with the longest wavelength, the highest frequency, and the largest wave speed. Record the measurements of each group's efforts on the board.



# TIME

# SCIENCE AND HISTORY

SCIENCE
CAN CHANGE
THE COURSE
OF HISTORY!

## **MAKING WAVES**

Sonar Helps Create Deep-Sea Pictures and Save Lives

This machine houses side-scan sonar. It was used to help locate the wreck of the *Titanic*.

## What is sonar?

Sonar is a device that uses sound waves to locate and measure the distance to underwater objects. Its name is a shortened version of SOund NAvigation and Ranging.

## **How does sonar work?**

Sonar sends out a ping sound that reflects back when it hits an underwater object. Because sound travels through water at a known speed (about 1,500 m/s), scientists measure how long the sound takes to return, then they calculate the distance.

## Why was it invented?

Sonar was developed by scientists in the early twentieth century as a way to detect icebergs and prevent boating disasters. Its technical

The Titanic was found thanks to sonar.

advancement was hurried by the Allies' need to detect German submarines in World War I. By 1918, the United States and Great Britain had developed an active sonar system placed in submarines sent to attack other subs.

By World War II, sonar allowed ships to defend themselves effectively from enemy subs. The strategy was to use sonar to find subs and then fire depth charges at them from a safe distance. After the war, sonar-absorbing hulls and quiet engines and machinery ensured that subs could partly shield themselves from sonar.

Sonar is now used to help find schools of fish. Oceanographers also use it to map ocean and lake floors. Sonar has been vital, too, in the discovery of sunken airplanes and ships.

In 1985, a French and American team used a new type of sonar device called side-scan sonar to locate the *Titanic*, the passenger liner that sank in 1912. This kind of sonar projects a tight beam of sound to create detailed images of the sea bed. Members of the expedition towed this sonar device about 170 m above the seabed across a section of the Atlantic Ocean where the *Titanic* went down. Weeks later, video cameras finally spotted the wreck.

**Report** Research how sonar was used by navies in World War I and World War II. Did sonar affect each war's outcome? How did it save lives? What uses can you think of for sonar if it could be used in everyday life?



## Reviewing Main Ideas

## **Section 1** The Nature of Waves

- 1. Waves are rhythmic disturbances that transfer energy through matter or space.
- **2.** Waves transfer only energy, not matter.



- **3.** Mechanical waves need matter to travel through. Mechanical waves can be compressional or transverse.
- **4.** When a transverse wave travels in a medium, matter in the medium moves at right angles to the direction the wave travels.
- **5.** When a compressional wave travels in a medium, matter moves back and forth along the same direction that the wave travels.

## **Section 2** Wave Properties

- 1. The movement of high points in a medium, called crests, and low points, called troughs, forms a transverse wave.
- **2.** The movement of more-dense regions, called compressions, and less-dense regions, called rarefactions, forms a compressional wave.

- **3.** Transverse and compressional waves can be described by their wavelengths, frequencies, periods, and amplitudes. As frequency increases, wavelength always decreases.
- **4.** The greater a wave's amplitude is, the more energy it transfers.



**5.** A wave's velocity can be calculated by multiplying its frequency times its wavelength.

## Section 3 The Behavior of Waves

- **1.** For all waves, the angle of incidence equals the angle of reflection.
- **2.** A wave is bent, or refracted, when it changes speed as it enters a new medium.
- **3.** When two or more waves overlap, they combine to form a new wave. This process is called interference.



FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review waves.

## **Using Vocabulary**

amplitude p. 288 rarefaction p. 294 compressional wave p.290 refraction p. 302 crest p. 294 resonance p.309 diffraction p. 304 standing wave p. 308 frequency p. 295 transverse wave p. 290 interference p.306 trough p. 294 medium p. 289 wave p. 298 period p. 295 wavelength p. 295

Answer the following questions using complete sentences.

- 1. Compare and contrast reflection and refraction.
- 2. Which type of wave has points called nodes that do not move?
- **3.** Which part of a compressional wave has the lowest density?
- **4.** Find two words in the vocabulary list that describe the bending of a wave.
- **5.** What occurs when waves overlap?
- **6.** What is the relationship among amplitude, crest, and trough?
- **7.** What does frequency measure?
- **8.** What does a mechanical wave always travel through?

## **Checking Concepts**

Choose the word or phrase that best answers each question.

- **9.** Which of the following do waves transfer?
  - A) matter
- **C)** matter and energy
- **B)** energy
- **D)** the medium
- **10.** What is the formula for calculating wave speed?
  - A)  $v = \lambda f$
- $\mathbf{C)} \ \ \nu = \lambda \ / \ f$
- **B)**  $v = f \lambda$
- **D)**  $v = \lambda + f$

- **11.** When a compressional wave travels through a medium, which way does matter in the medium move?
  - A) backward
  - **B)** forward
  - c) perpendicular to the rest position
  - **D)** along the same direction the wave travels
- **12.** What is the highest point of a transverse wave called?
  - A) crest
- **C)** wavelength
- **B)** compression
- **D)** trough
- **13.** If the frequency of the waves produced by a vibrating object increases, how does the wavelength of the waves produced change?
  - **A)** It stays the same. **C)** It vibrates.
- - **B)** It decreases.
- **D)** It increases.
- 14. If the amplitude of a wave changes, which of the following changes?
  - **A)** wave energy
- **C)** wave speed
- **B)** frequency
- **D)** refraction
- **15.** Which term describes the bending of a wave around an object?
  - A) resonance
- **c)** diffraction
- **B)** interference
- **D)** reflection
- **16.** What is equal to the angle of reflection?
  - **A)** refraction angle
- **c)** bouncing angle
  - **B)** normal angle
- **D)** angle of incidence

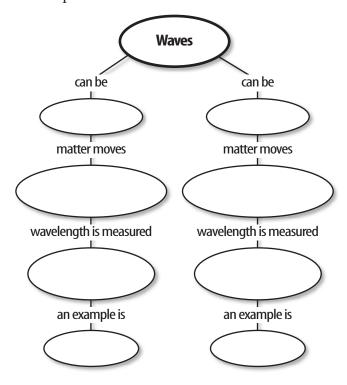
Use the table below to answer question 17.

Speed of Sound in Air				
Temperature (°C)	Sound Speed (m/s)			
0	331.4			
10	337.4			
20	343.4			

- **17.** Based on the data in the table above, which of the following would be the speed of sound in air at 30°C?
  - **A)** 340.4 m/s
- **c)** 353.4 m/s
- **B)** 346.4 m/s
- **D)** 349.4 m/s

#### Interpreting Graphics

**18.** Copy and complete the following concept map.



## **Thinking Critically**

- **19.** Explain An earthquake on the ocean floor produces a tsunami that hits a remote island. Is the water that hits the island the same water that was above the earthquake on the ocean floor?
- **20. Compare** Suppose waves with different amplitudes are produced by a vibrating object. How do the frequencies of the waves with different amplitudes compare?
- **21. Explain** Use the law of reflection to explain why you see only a portion of the area behind you when you look in a mirror.
- 22. Explain why you can hear a fire engine coming around a street corner before you can see it.

- **23.** Describe the objects or materials that vibrated to produce three of the sounds you've heard today.
- **24.** Form a Hypothesis In 1981, people dancing on the balconies of a Kansas City, Missouri, hotel caused the balconies to collapse. Use what have you learned about wave behavior to form a hypothesis that explains why this happened.
- 25. Make and Use Tables Find information in newspaper articles or magazines describing five recent earthquakes. Construct a table that shows for each earthquake the date, location, magnitude, and whether the damage caused by the earthquake was light, moderate, or heavy.
- **26.** Concept Map Design a concept map that shows the characteristics of transverse waves. Include the terms *crest*, *trough*, medium, wavelength, frequency, period, and *amplitude*.

## **Applying Math**

- **27.** Calculate Wavelength Calculate the wavelength of a wave traveling on a spring if the wave moves at 0.2 m/s and has a period of 0.5 s.
- **28.** Calculate Wavespeed The microwaves produced inside a microwave oven have a wavelength of 12.0 cm and a frequency of 2,500,000,000 Hz. At what speed do the microwaves travel in units of m/s?
- **29. Calculate Frequency** Water waves on a lake travel toward a dock with a speed of 2.0 m/s and a wavelength of 0.5 m. How many wave crests strike the dock each second?

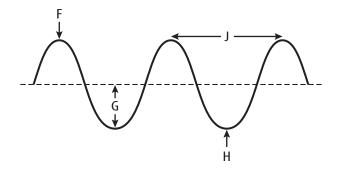
## Standardized Test Practice chapter

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### Multiple Choice

- **1.** When a transverse wave travels through a medium, which way does matter in the medium move?
  - A. backward
  - **B.** in all directions
  - **c.** at right angles to the direction the wave travels
  - **D.** in the same direction the wave travels

Use the illustration below to answer questions 2 and 3.



- **2.** What wave property is shown at G?
  - **A.** amplitude
  - B. wavelength
  - **C.** crest
  - **D.** trough
- **3.** What property of the wave is shown at H?
  - **A.** amplitude
  - **B.** wavelength
  - **C.** crest
  - **D.** trough

Use the illustration below to answer questions 4 and 5.



- **4.** What kind of wave is shown?
  - **A.** mechanical
  - **B.** compressional
  - **C.** transverse
  - **D.** both A and B
- **5.** What happens to the yarn tied to the coil?
  - **A.** It moves back and forth as the wave passes.
  - **B.** It moves up and down as the wave passes.
  - **C.** It does not move as the wave passes.
  - **D.** It moves to the next coil as the wave passes.
- **6.** What kind of waves are the seismic waves produced during an earthquake?
  - **A.** transverse
  - **B.** compressional
  - **c.** combination of transverse and compressional
  - **D.** electromagnetic

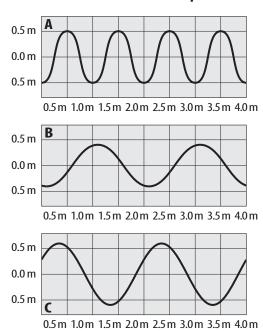
- **7.** What is the bending of a wave as it enters a new material called?
  - A. refraction
  - **B.** diffraction
  - **C.** reflection
  - **D.** interference

#### **Gridded Response**

- **8.** A tuning fork vibrates at a frequency of 256 Hz. The wavelength of the sound produced by the tuning fork is 1.32 m. What is the speed of the wave in m/s?
- **9.** A wave has a speed of 345 m/s and its frequency is 2050 Hz. What is its wavelength in m?

## Short Response

Use the illustration below to answer questions 10 and 11.

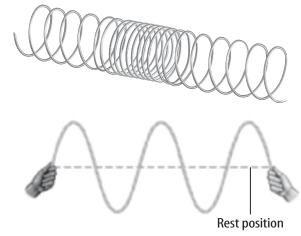


- **10.** Determine the amplitudes and the wavelengths of each of the three waves.
- **11.** If the length of the *x*-axis on each diagram represents 2 s of time, what is the frequency of each wave?

## Extended Response

**12.** In a science fiction movie, a huge explosion occurs on the surface of a planet. People in a spaceship heading toward the planet see and hear the explosion. Is this realistic? Explain.

Use the illustrations below to answer question 13.



- **13.** The illustrations show two mechanical waves.
  - **Part A** Describe how the amplitude of each of the two waves shown is defined.
  - **Part B** Describe how you would change both drawings to show waves that transfer more energy.

#### Test-Taking Tip

**Answer Every Question** Never leave any open-ended answer blank. Answer each question as best you can. You can receive partial credit for partially correct answers.

Question 12 Before you answer the question, list what you know about light waves and sound waves.

# chapter 11

#### BIG (Idea

Sound and light are waves that are described by their frequency, amplitude, and wavelength.

#### **11.1 Sound**

MAIN (Idea Sound waves are compressional waves generated by a vibrating object.

## 11.2 Reflection and Refraction of Light

MAIN (Idea Light waves can be absorbed, transmitted, or reflected when they interact with matter.

## 11.3 Mirrors, Lenses, and the Eye

MAIN (Idea Images of objects seen by the eye can be changed by mirrors and lenses.

## 11.4 Light and Color

MAIN (Idea) The color of an object depends on the wavelengths of light emitted or reflected by the object.

## Cracking the Sound Barrier

Have you ever heard the crack of a sonic boom? A sonic boom occurs when a plane exceeds the speed of sound. Sound waves create a cone-shaped shock wave coming from the aircraft. Behind the cone are low-pressure regions that can cause water vapor to condense, forming the cloud you see here.

#### **Science Journal**

Write three things you would like to learn about sound.



## **Start-Up Activities**



#### What sound does a ruler make?

Musical instruments come in many shapes and sizes. Some have strings, some have hollow tubes, and others have keys or pedals. They are played with various techniques. These differences give each instrument a unique sound. What would an instrument made from a ruler sound like?

- 1. Complete the safety form.
- 2. Firmly hold one end of a thin ruler lying flat on a desk, allowing the free end to extend beyond the edge of the desk.
- **3.** Gently pull up on and release the end of the ruler. What do you see and hear?
- **4.** Vary the length of the overhanging portion and repeat the experiment several times.
- 5. Think Critically In your Science Journal, write instructions for playing a song with the ruler. Explain how the length of the overhanging part of the ruler affects the sound.



**Sound and Light** Make the following Foldable to help you identify ways in which sound and light are different and alike.

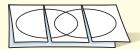
**STEP 1** Fold one sheet of paper lengthwise.



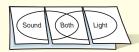
**STEP 2** Fold into thirds.



STEP 3 Unfold and draw overlapping ovals.
Cut the top sheet along the folds.



**STEP 4 Label** the ovals as shown.



**Constructing a Venn Diagram** As you read the chapter, list the characteristics unique to sound under the left tab, the characteristics unique to light under the right tab, and those common to both under the middle tab.



Preview this chapter's content and activities at qpescience.com

## **Reading Guide**

## What You'll Learn

- Explain how sound travels through different mediums.
- Explain different properties of sound.
- **Discuss** the Doppler effect.
- Identify ways sound can be used.

## Why It's Important

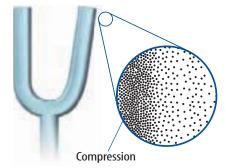
Sounds are one way that you learn about the world around you.

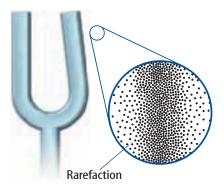
## Review Vocabulary

**vibration:** rhythmic back-and-forth motion

#### **New Vocabulary**

- intensity
- loudness
- decibel
- pitch
- Doppler effect





**Figure 1** A vibrating tuning fork produces compressions and rarefactions that travel outward from the tuning fork. These compressions and rarefactions form a sound wave.

## **Sound Waves**

An amusement park can be a noisy place. With all the racket of carousel music and booming loudspeakers, it can be hard to hear what your friends say. The many sounds you hear every day are different, but they do have something in common—each sound is produced by an object that vibrates.

**Making Sound Waves** When an object like the tuning fork in **Figure 1** vibrates, it creates sound waves. Sound waves are compressional waves. Recall that a compressional wave is made of compressions and rarefactions. When an end of the tuning fork moves outward, it forms a compression on that side by pushing the molecules in air together. The compression moves away from the tuning fork as these molecules collide with other molecules in air. When the end of the tuning fork moves back, a rarefaction is formed where the molecules are farther apart. As the tuning fork vibrates, it produces a series of compressions and rarefactions that travels outward. This series of compressions and rarefactions is the sound wave that you hear.

## **The Speed of Sound**

A sound wave moves in air as collisions between the molecules in air transfer energy from place to place. Sound waves also can move in other materials. The material in which a sound wave moves is called a medium. Just as in air, sound waves travel in solids, liquids, and other gases as a vibrating object transfers energy to the particles in the material. However, sound waves cannot travel in empty space where there are no particles.

**The Speed of Sound in Different Materials** The speed of a sound wave in a medium depends on the type of substance and whether it is a solid, liquid, or gas. For example, **Table 1** shows the speed of sound in different mediums at room temperature. In general, sound travels slowest in gases and fastest in solids.

**Temperature and the Speed of Sound** The speed of sound waves also depends on the temperature of the medium. As the temperature of a substance increases, its atoms and molecules move faster. At a higher temperature, atoms and molecules collide with each other more frequently. As a result, sound waves move faster. For example, in air at a temperature of 0°C, sound travels at a speed of 331 m/s, but in air at a temperature of 20°C, sound travels at 343 m/s.

<b>Amplitude</b>	and Energy	of Sound	<b>Waves</b>
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Think about the differences among sounds you hear. Some are loud; others are soft. The flute plays high notes, whereas the tuba is much lower. What properties of sound waves cause these differences in the sounds you hear?

Recall that the amount of energy a wave carries corresponds to its amplitude. For a compressional wave, amplitude is related to the density of the particles in the compressions and rarefactions. A vibrating object makes a wave by transferring energy to the medium. More energy is transferred to the medium when the particles of the medium are forced closer together in the compressions and spread farther apart in the rarefactions. Look at **Figure 2.** A sound wave has a higher amplitude and carries more energy when particles in the medium are closer together in the compressions and more spread out in the rarefactions.

Figure 2 The amplitude of a
sound wave depends on the density
of the particles in the compressions

Table 1 Speed of Sound

**Speed of Sound** 

(m/s)

343

500

1,498

3,650

5,000

in Different Mediums

Medium

Air (20°C)

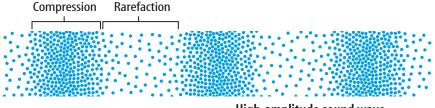
Cork

Water

Brick

Aluminum

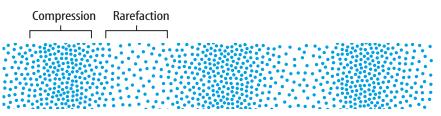
In a high-amplitude sound wave, particles are tightly packed in the compressions and far apart in the rarefactions.



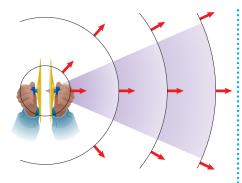
High-amplitude sound wave

and rarefactions.

In a low-amplitude sound wave, particles are less tightly packed in the compressions and not as far apart in the rarefactions.



Low-amplitude sound wave



**Figure 3** The intensity of a sound wave decreases as the wave spreads out from the source of the sound. The energy of the wave is spread over a larger area as the wave spreads out.

**Intensity and Loudness** 

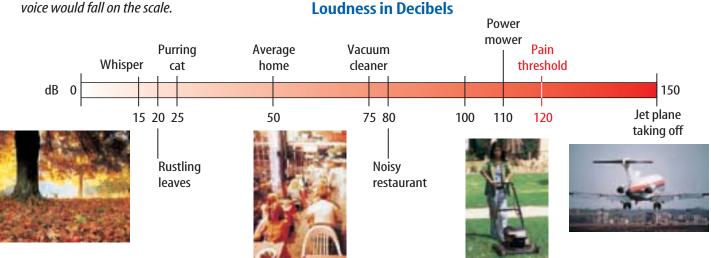
Imagine you are listening to music from your CD player. Sound waves produced by the CD player travel through the air and transfer energy from the CD player to your ears. The energy that reaches your ears depends not only on the amplitude of the sound waves, but also on how close you are to the CD player. **Figure 3** shows that as you get farther from a source of sound, the energy of the sound waves is spread over a greater area. The amount of energy transferred by a sound wave through a certain area each second is the **intensity** of the sound wave. As sound waves travel away from the source of the sound, the intensity of the waves decreases as the waves spread out. This means that as you get farther from the source, less energy reaches your ears each second.

**Loudness** When you hear different sounds, you do not need special equipment to know which sounds have greater intensity. Your ears and brain can tell the difference. **Loudness** is the human perception of sound intensity. As the intensity of a sound wave increases, the loudness of the sound also increases.

Reading Checke How are intensity and loudness related?

A Scale for Sound Intensity The intensity of sound can be described using a measurement scale. Each unit on the scale for sound intensity is called a decibel, abbreviated dB. On this scale, the faintest sound that most people can hear is 0 dB. Sounds with intensity levels above 120 dB may cause pain and permanent hearing loss. During some rock concerts, sounds reach this damaging intensity level. Wearing ear protection, such as earplugs, around loud sounds can help protect against hearing loss. **Figure 4** shows some sounds and their intensity levels in decibels.

**Figure 4** The decibel scale measures the intensity of sound. **Identify** where a normal speaking voice would fall on the scale.



## **Pitch and Frequency**

You might be familiar with the music scale do, re, mi, fa, sol, la, ti, do shown in **Figure 5.** If you were to sing this scale, you would hear the pitch of your voice get higher. **Pitch** is the human perception of the frequency of sound waves. Pitch gets higher as the frequency of the sound waves increases.

			0	0	0	0	0
•	0	<b>-o</b> -					
C	D	Е	F	G	Α	В	C
do	re	mi	fa	sol	la	ti	do
262 Hz	294 Hz	330 Hz	349 Hz	392 Hz	440 Hz	494 Hz	523 Hz

**Frequency** Frequency is a measure of how many wavelengths pass a particular point each second. For a compressional wave, such as sound, the frequency is the number of compressions or the number of rarefactions that pass by each second. Frequency is measured in hertz (Hz). A frequency of 1 Hz means that one complete wavelength passes by in 1 s.

A healthy human ear can hear sound waves with frequencies from about 20 Hz to 20,000 Hz. The human ear is most sensitive to sounds in the range of 440 Hz to about 7,000 Hz. In this range, most people can hear much fainter sounds than they can at higher or lower frequencies.

**Ultrasonic and Infrasonic Waves** Most people can't hear sound frequencies above 20,000 Hz, which are called ultrasonic waves. Dogs can hear sounds with frequencies up to about 35,000 Hz, and bats can detect frequencies higher than 100,000 Hz. Even though humans can't hear ultrasonic waves, they have a number of uses. For example, ultrasonic waves directed into the human body are used in medical diagnosis and treatment. Ultrasonic waves are reflected by objects underwater, and can be used to determine the size, shape, and depth of underwater objects.

Infrasonic, or subsonic, waves have frequencies below 20 Hz—too low for most people to hear. These waves are produced by sources that vibrate slowly, such as wind, heavy machinery, and earthquakes. Although you can't hear infrasonic waves, you might feel them as a rumble inside your body.

## The Doppler Effect

Imagine that you are standing at the side of a racetrack with race cars zooming past. As they move toward you, the pitches of their engines become higher. As they move away, the pitches become lower. The change in pitch or frequency due to the relative motion of a wave source is called the **Doppler effect.** 

**Figure 5** Every note has a different frequency, which gives it a distinct pitch.

**Describe** how pitch changes when frequency increases.



#### **Comparing Intensity**

## Procedure

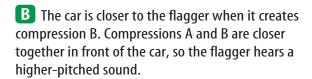
- 1. Complete the safety form.
- 2. Tie the middle of a 50-cm length of string to a metal object such as a spoon.
- 3. Wrap each end of the string around a finger on each hand. Place one of these fingers in each ear.
- **4.** Swing the object so it bumps against a **table** or a **chair**. Note the sound.
- **5.** Take your fingers out of your ears and repeat step 4.

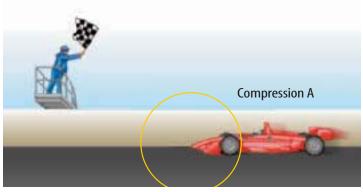
#### **Analysis**

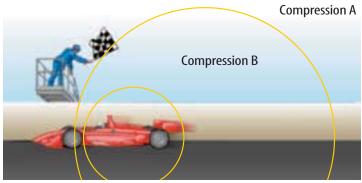
- **1.** Compare the sounds you heard in both trials.
- 2. Compare the intensity of the sound waves that reached your ears in both trials.

**Figure 6** The Doppler effect occurs when the source of a sound wave is moving relative to a listener.

A The race car creates compression A, which spreads through the air in all directions from the point where it was created.







A Moving Source of Sound As a race car moves, it produces sound waves in the form of compressions and rarefactions. In Figure 6A, the race car creates a compression, labeled A. Compression A moves through the air toward the flagger. By the time compression B leaves the race car in Figure 6B, the car has moved forward. Because the car has moved since the time it created compression A, compressions A and B are closer together in front of the car than they would be if the car had stayed still. Because the compressions are closer together, more compressions pass by the flagger each second than if the car had been at rest. As a result, the flagger hears a higher pitch. Figure 6B also shows that the compressions behind the moving car are farther apart, resulting in a lower frequency. The flagger hears a lower pitch after the car passes.

A Moving Listener You also can hear the Doppler effect when you are moving past a sound source that is standing still. Suppose you were riding in a school bus and passed a building with a ringing bell. The pitch would become higher as you approached the building and lower as you rode away from it. The Doppler effect happens any time the source of a sound is changing position relative to the listener. It occurs no matter whether it is the sound source or the listener that is moving. The faster the change in position, the greater the change in frequency and pitch.



How does pitch change if you are moving away from a sound source?



Red Shift The Doppler effect can also be observed in light waves emanating from moving sources—although the sources must be moving at tremendous speeds. Astronomers have learned that the universe is expanding by observing the Doppler effect in light waves. Research the phenomenon known as red shift and explain in vour Science Journal how it relates to the Doppler effect.

## **Using Sound**

When sound waves strike an object, they can be absorbed by the object, transmitted through the object, or reflected from the object. By detecting the sound waves reflected from an object, the size, shape, and location of an object can be determined.

**Echolocation and Sonar** Some species of bats, as well as dolphins, whales, and other animals, use sound waves to detect their prey. Echolocation is the process of locating objects by emitting sounds and detecting the sound waves that reflect back.

Sonar is a system that uses the reflection of underwater sound waves to detect objects. First, a sound pulse is emitted underwater. The sound waves travel in the water and are reflected when they strike an object, such as a fish or a ship. An underwater microphone detects the reflected waves. Because the speed of sound in water is known, the distance to the object can be calculated by measuring how much time passes between when the sound pulse is emitted and when the reflected signal is received.



#### **Topic: Sonar**

Visit **gpescience.com** for Web links to information about ways sonar is used.

**Activity** Research to find out the different types of sonar. Make a poster that describes active and passive sonar.

## **Applying Math**

## **Solve a Simple Equation**

**USING SONAR** A sonar pulse returns in 3.00 s from a sunken ship that is directly below. Find the depth of the ship if the speed of the pulse is 1,500 m/s. *Hint*: The sonar pulse travels a distance equal to twice the depth of the ship, so use the equation d = st/2 to find the depth.

#### IDENTIFY known values and the unknown value

Identify the known values:

speed of sound in water means 
$$s = 1,500 \text{ m/s}$$
  
time for round trip means  $t = 3.00 \text{ s}$ 

Identify the unknown value:

depth of the ship 
$$d = ? m$$

## SOLVE the problem

Substitute the known values s = 1,500 m/s and t = 3.00 s into the equation for depth:

$$d = \frac{st}{2} = \frac{(1,500 \text{ m/s})(3.00 \text{ s})}{2} = \frac{1}{2}(4,500 \text{ m}) = 2,250 \text{ m}$$

#### **CHECK** your answer

Check your answer by dividing the distance by the time and multiplying by 2. The result should be the speed of sound given in the problem.

#### **Practice Problems**

Find the speed of a sonar pulse that returns in 2.0 s from a ship at a depth of 1,500 m. For more practice problems go to page 879, and visit Math Practice at gpescience.com.



**Figure 7** Ultrasonic waves are directed into a pregnant woman's uterus to form images of her fetus.

**Ultrasound in Medicine** High-frequency sound waves can also be used to remove dirt buildup on jewelry and glassware. One of the most important uses of ultrasonic waves, though, is in medicine. Using special instruments, medical professionals can send ultrasonic waves into a specific part of a patient's body. Reflected ultrasonic waves are used to examine different body parts and to detect and monitor certain types of heart disease and cancer. Ultrasound imaging also is used to monitor the development of a fetus, as shown in **Figure 7.** However, ultrasound does not produce good images of the bones and lungs, because hard tissues and air absorb the ultrasonic waves instead of reflecting them.

High-frequency sound waves can be used to treat certain medical problems. For example, sometimes small, hard deposits of calcium compounds or other minerals form in the kidneys, making kidney stones. In the past, physicians had to perform surgery to remove kidney stones. Now ultrasonic treatments are commonly used to break them up instead. Bursts of ultrasound create vibrations that cause the stones to break into small pieces that can easily pass out of the body with the urine. A similar treatment is available for gallstones.

## section

## review

#### **Summary**

#### **Sound Waves**

- Sound waves are compressional waves that are produced by vibrating objects.
- Sound usually travels fastest in solids and slowest in gases.
- Sound travels faster as the temperature of the medium increases.

#### **Properties of Sound**

- The amplitude of sound waves increases as the density of particles increases in the compressions and decreases in rarefactions
- Loudness is the human perception of the intensity of sound waves. Pitch is the human perception of the frequency of sound waves.
- The Doppler effect is the change in the frequency of a sound wave when the source of the sound is moving relative to a listener.

#### **Self Check**

- 1. Explain how sound travels from your vocal cords to your friend's ears when you talk.
- **2. Explain** how the loudness of a sound wave depends on the intensity of the sound wave.
- 3. Draw and label a diagram that explains the Doppler
- 4. **Describe** at least three uses of ultrasonic technology in medicine.
- 5. Think Critically How could sonar technology be used to locate deposits of oil and minerals?

## **Applying Math**

- **6. Calculate Time** How long would it take a sound wave from a car alarm to travel 1.0 km in air if the air temperature were 0°C?
- **7. Calculate Distance** If sound travels in the ocean with a speed of 1,500 m/s, how far will a sonar pulse travel in 45 s?



# Reflection and **Refraction of Light**

## **Reading Guide**

## What You'll Learn

- with matter.
- **Explain** the difference between regular and diffuse reflection.
- **Define** the index of refraction of a
- **Explain** why a prism separates white light into different colors.

## Why It's Important

**Describe** how light waves interact The images you see every day are due to the behavior of light waves.

## Review Vocabulary

visible light: an electromagnetic wave with wavelengths between about 400 and 700 billionths of a meter

#### New Vocabulary

- opaque
- translucent
- transparent
- index of refraction

## The Interaction of Light and Matter

Look around your darkened room at night. You know that some of the objects are brightly colored, but they look gray or black in the dim light. Turn on the light, and you can see all the objects in the room clearly, including their colors. What you see depends on the amount of light in the room and the color of the objects. For you to see an object, it must reflect or emit some light that reaches your eyes.

Absorption, Transmission, and Reflection Objects can absorb light, reflect light, and transmit light—allow light to pass through them. The type of matter in an object determines the amount of light it absorbs, reflects, and transmits. For example, the opaque material in the top candleholder in Figure 8 only absorbs and reflects light—no light passes through it. As a result, you cannot see the candle inside. Materials that allow some light to pass through them, like the material of the middle candleholder in **Figure 8**, are described as **translucent**. You cannot see clearly through translucent materials.

**Transparent** materials, such as the bottom candleholder in Figure 8, transmit almost all the light striking them, so you can see objects clearly through them. Only a small amount of light is absorbed and reflected by transparent materials.

**Figure 8** These candleholders interact with light differently.



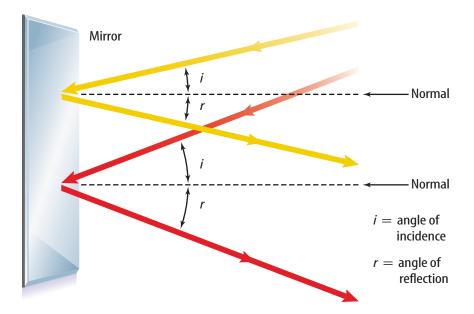
A Opaque



**B** Translucent



Transparent



**Figure 9** According to the law of reflection, light is reflected so that the angle of incidence always equals the angle of reflection.

**Reflection of Light** 

Have you glanced in a mirror today? You see your reflection in the mirror when light is reflected off you, strikes the mirror, and is reflected off the mirror into your eye. Because light behaves as a wave, it obeys the law of reflection, as shown in **Figure 9.** Recall that, according to the law of reflection, the angle at which a light wave strikes a surface is the same as the angle at which it is

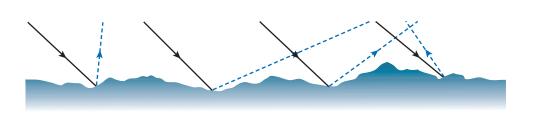
reflected. Light reflected from any surface—a mirror or a sheet of paper—obeys this law.

**Regular and Diffuse Reflection** Why can you see your reflection in a store window but not in a sheet of paper? The answer has to do with the smoothness of the surfaces. A smooth, even surface such as a pane of glass produces a sharp image by reflecting parallel light waves in only one direction. Reflection of light waves from a smooth surface is regular reflection. To cause a regular reflection, the roughness of a surface must be less than the wavelengths it reflects. A sheet of paper has an uneven surface that causes incoming parallel light waves to be reflected in many directions, as shown in **Figure 10.** Reflection of light from a rough surface is diffuse reflection.

**Scattering** Diffuse reflection is a type of scattering that occurs when light waves traveling in one direction are made to travel in many different directions. Scattering also occurs when light waves traveling through the air reflect off small particles. An example is light scattering off the small water droplets that make up a cloud. Scattering causes the cloud to appear white, even though the droplets are transparent.



**Figure 10** A sheet of paper has an uneven surface that produces a diffuse reflection. **Explain** Use the law of reflection to explain why a rough surface causes parallel *light waves to be reflected in* many directions.



## **Refraction of Light**

What occurs when a light wave passes from one material to another—from air to water, for example? Recall that refraction is caused by a change in the speed of a wave when it passes from one material to another. If the light wave is traveling at an angle to the boundary between the materials and the speed of light is different in the two materials, the wave will be bent, or refracted.

Reading Check Why does refraction occur?

**The Index of Refraction** The amount of bending that takes place depends on the speeds of light in both materials. The greater the change in speed, the more the light will be bent as it passes at an angle from one material to the other. **Figure 11** shows an example of refraction. Every material has an **index of refraction** which is the ratio of the speed of light in a vacuum to the speed of light in the material. The index of refraction indicates how much the speed of light is reduced in the material compared to its speed in empty space.

The larger the index of refraction, the more light is slowed down in the material. For example, because glass has a larger index of refraction than air, light moves more slowly in glass than air. The index of refraction is usually largest for solids and smallest for gases.

**Prisms** A sparkling glass prism hangs in a sunny window, refracting the sunlight and projecting a colorful pattern onto the walls of the room. How does the refraction of light create these colors? The spectrum of colors is produced because the speed of

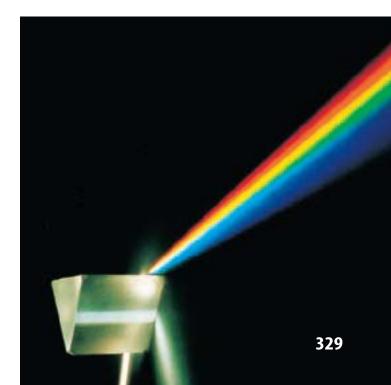
light in a material also depends on the wavelength of the light. In a glass prism, light waves with longer wavelengths, such as red light waves, are slowed less than light waves with shorter wavelengths, such as blue light waves.

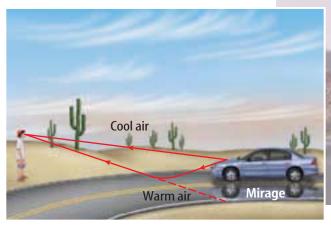
**Figure 12** shows what occurs when white light passes through a prism. White light, such as sunlight, is made up of light waves with range of wavelengths from red to blue. The triangular prism refracts the light twice—once when it enters the prism and again when it leaves the prism and reenters the air. Because the longer wavelengths of light are slowed less than the shorter wavelengths are, red light is bent the least. As a result of these different amounts of bending, the different colors are separated when they emerge from the prism.



**Figure 11** The spoon looks broken because light waves are refracted as they change speed when they pass from the water to the air.

**Figure 12** Refraction causes a prism to separate a beam of white light into different colors.







**Figure 13** Mirages result when air near the ground is much warmer or cooler than the air above. This causes light waves reflected from an object to refract, creating one or more additional images.

**Mirages** When you're traveling in a car, you might see what looks like a pool of water on the road ahead. As you get closer, the water seems to disappear. You've seen a mirage—an image of a distant object produced by the refraction of light through air layers of different densities. Mirages result when the air at ground level is much warmer or cooler than the air above, as shown in **Figure 13.** The density of air increases as air cools and light waves move slower in cooler air than in warmer air. As a result, light waves are refracted as they pass through air layers with different temperatures.

## section

## review

#### **Summary**

#### **Light and Matter**

 The amount of light that is absorbed, reflected, or transmitted depends on the material making up the object.

#### **Reflection of Light**

- Light waves always obey the law of reflection: the angle of incidence equals the angle of reflection.
- Regular reflection causes parallel light waves to be reflected in only one direction.
- Diffuse reflection causes parallel light waves to be reflected in many directions.
- Scattering occurs when light waves are reflected and travel in many different directions.

#### **Refraction of Light**

- Refraction occurs when a light wave changes speed in moving from one material to another.
- The index of refraction of a material indicates how much light slows down in the material.

#### **Self Check**

- 1. Compare and contrast opaque, transparent, and translucent materials. Give one example of each.
- 2. Discuss why you can see your reflection in a smooth piece of aluminum foil but not in a crumpled ball of foil.
- 3. Infer what happens to light waves that are reflected off dust particles in the air.
- **4. Explain** what happens to white light when it passes through a prism.
- **5. Think Critically** Suppose a material has the same index of refraction as water. How would a light wave change direction as it traveled from water into this material?

#### **Applying Math**

- **6. Find an Angle** A light wave strikes a mirror at an angle of 42° from the surface of the mirror. What angle does the reflected wave make with the normal?
- 7. Find an Angle A light wave reflects from a mirror at 27° from the normal. What was the angle between the mirror and the incident wave?

# Mirrors, Lenses, and the Eye

## **Reading Guide**

## What You'll Learn

- Describe how images are formed by three types of mirrors.
- **Explain** how convex and concave lenses form images.
- Explain how the human eye enables you to see.
- Describe how lenses are used to correct vision problems.

## Why It's Important

Mirrors and lenses are used in optical instruments such as cameras and telescopes.

## Review Vocabulary

reflection: the process of changing direction after striking a surface

#### **New Vocabulary**

- plane mirror
- concave mirror
- convex mirror
- convex lens
- concave lens

## **Light Rays**

Light sources send out light waves in all directions. These waves spread out like ripples on the surface of water spread out from the point of impact of a pebble. You can think of the light coming from the source as being many narrow beams of light traveling in all directions. Each narrow light beam is called a light ray.

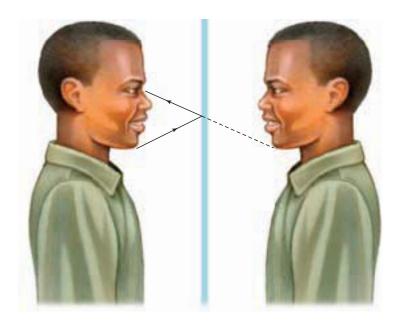
## **Mirrors**

A mirror is any surface that produces a regular reflection. A pool of still water, a metal pan, and even the back of a shiny spoon can be mirrors. Mirrors can be flat, curved inward, or curved outward.

**Plane Mirrors** A flat, smooth mirror is a plane mirror. When you look in a plane mirror, your image appears upright. If you stand 1 m from the mirror, your image appears 1 m behind the mirror, or 2 m from you. In fact, your image is what a friend standing 2 m from you would see. Figure 14 shows how your image is formed. First, light rays from a light source strike you. Every point that is struck by the light rays reflects these rays so they travel outward in all directions. If your friend were looking at you, these reflected light rays coming from you would enter her eyes so she could see you. However, if a mirror is placed between you and your friend, light rays are reflected from the mirror back to your eyes.

**Figure 14** Seeing an image of yourself in a mirror involves two sets of reflections: light rays are reflected from you and then are reflected by the mirror.





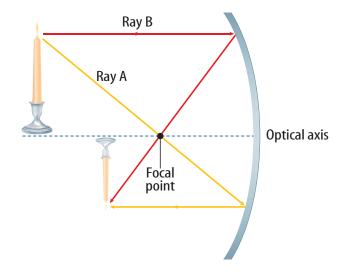
**Figure 15** Your brain interprets the light rays reflected by the mirror as coming from a point behind the mirror. **Infer** how the size of your image in a plane mirror depends on your distance from the mirror.

Virtual and Real Images The formation of an image by a plane mirror is shown in **Figure 15.** Your brain assumes that light rays travel in a straight line. As a result, rays that enter your eyes seem to come from behind the mirror. This makes the image seem to be behind the mirror. However, no light rays actually pass through the place where the image seems to be located. This type of image is called a virtual image. Plane mirrors always form virtual images. If light rays from an object pass through the location of the image, the image is called a real image. Curved mirrors can form both real and virtual images.

**Concave Mirrors** If the surface of a mirror is curved inward, it is called a **concave mirror**, as shown in **Figure 16.** The optical axis is an imaginary straight line drawn perpendicular to the surface of the mirror at its center. Every light ray traveling parallel to the optical axis is reflected through a point on the optical axis called the focal point. The distance from the center of the mirror to the focal point is called the focal length.

The image formed by a concave mirror depends on the location of the object relative to the focal point. Figure 16 shows a candle located more than twice the focal length from the mirror. Although many light rays come from each point on the candle, only two rays from the same point are shown. Ray A passes through the focal point and then reflects off the mirror moving parallel to the optical axis. Ray B travels parallel to the optical axis before reflecting off the mirror and passing through the focal point. The point where the two rays meet is the location of the image of the original point on the candle. The image formed is a real image because light rays from the candle pass through the place where the image is located.

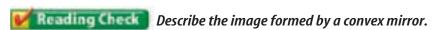
Figure 16 Rays A and B start from the same place on the candle, travel in different directions, and meet again on the reflected image. **Diagram** how two other points on the image of the candle are formed.



**Images Produced by a Concave Mirror** When an object is between one and two focal lengths from a concave mirror, the image is real, inverted, and larger than the object. An object closer than one focal length from a concave mirror produces a virtual image that is upright and larger than the object. No image is produced if the object is located at the focal point.

**Convex Mirrors** When you are in a store, look up toward one of the back corners or at the end of an aisle to see if a large, rounded mirror is mounted

there. You can see a large area of the store in such a mirror. A mirror that curves outward like the back of a spoon is called a convex mirror. Light rays that hit a convex mirror diverge, or spread apart, after they are reflected. Figure 17 shows how the rays from an object are reflected by a convex mirror to form an image. The reflected rays diverge and never meet, so a convex mirror forms only a virtual image. The image also is upright and smaller than the actual object is.

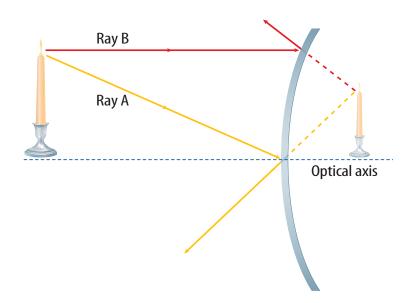


## Lenses

What do your eyes have in common with cameras, eyeglasses, and microscopes? Each of these contains at least one lens. A lens is a transparent object with at least one curved surface that causes light rays to refract. The image that a lens forms depends on the shape of the lens. Like curved mirrors, lenses can be convex or concave.

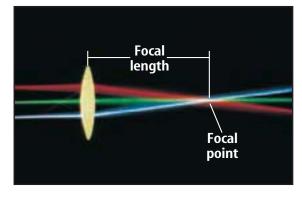
**Convex Lenses** A **convex lens** is thicker in the middle than at the edges. Its optical axis is an imaginary straight line that is perpendicular to the surface of the lens at its thickest point. When light

rays approach a convex lens traveling parallel to its optical axis, the rays are refracted toward the center of the lens, as in **Figure 18.** Light rays traveling along the optical axis are not bent at all. All light rays traveling parallel to the optical axis are refracted so they pass through a single point, which is the focal point of the lens. The less curved the sides of the lens, the less light rays are bent. As a result, lenses with flatter sides have longer focal lengths. Figure 19 on the next page shows that convex lenses can form either real or virtual images.



**Figure 17** A convex mirror forms a reduced, upright, virtual image.

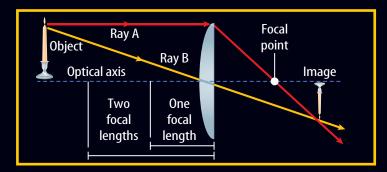
Figure 18 Convex lenses are thicker in the middle than at the edges. Light rays that are parallel to the optical axis are refracted so that they pass through the focal point. A light ray that passes through the center of the lens is not refracted.



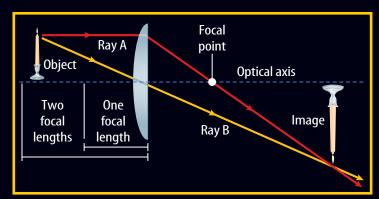
## Figure 19

convex lens can form images that are real or virtual, enlarged or reduced, and upright or inverted. Just as for a concave mirror, the type of image formed by a convex lens depends on the location of the object relative to the focal point of the lens.

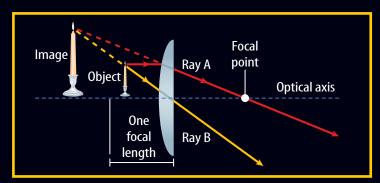
If the object is more than two focal lengths from the lens, the image formed is real, inverted, and smaller than the object. As the object moves farther from the lens, the image becomes smaller.



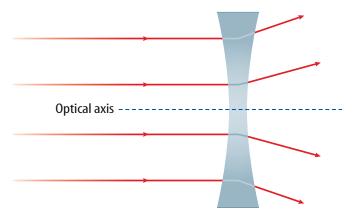
If the object is between one and two focal lengths from the lens, the image formed is real, inverted, and larger than the object. As the object moves closer to the focal point, the image becomes larger.



If the object is less than one focal length from the lens, the image is virtual, upright, and larger than the object. The image is virtual because the light rays from the object diverge after they pass through the lens. The image becomes smaller as the object moves closer to the lens.



**Concave Lenses** A concave lens is thinner in the middle and thicker at the edges. As shown in Figure 20, light rays that pass through a concave lens bend away from the optical axis. The rays spread out and never meet, so a real image is never formed. The image is always virtual, upright, and smaller than the object is. Concave lenses are used in some types of eyeglasses and some telescopes. Concave lenses usually are used in combination with other lenses.





Reading Check What type of image is formed by a concave lens?

## **The Human Eye**

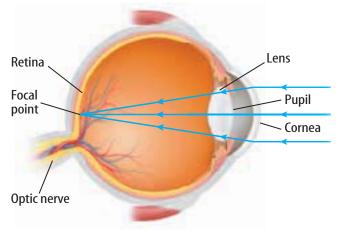
What determines how well you can see the words on this page? If you don't need eyeglasses, the structure of your eye gives you the ability to focus on these words and other objects around you. Look at **Figure 21.** Light enters your eye through a transparent covering on your eyeball called the cornea. The cornea causes light rays to bend so that they converge. The light then passes through an opening called the pupil. Behind the pupil is a flexible convex lens. Muscles attached to the lens change its shape to help focus light, forming a sharp image on your retina.

The retina is the inner lining of your eye. The retina contains light-sensitive cells that convert an image into electrical signals. These signals then are carried along the optic nerve to your brain to be interpreted. With this complex structure, the human eye is capable of seeing clearly in bright and dim conditions, focusing on both near and far objects, and also detecting colors.

Figure 20 A concave lens refracts light rays so they spread out away from the optical axis. **Classify** *Is a concave lens most* like a concave mirror or a convex mirror?



**Eye Doctors** Optometrists and ophthalmologists treat many different eve problems. They often use advanced technology to diagnose and correct malfunctioning parts of the eye. Research an eye problem and how it is treated. Write a paragraph describing what parts of the eye are affected by the problem and how doctors correct it.



**Figure 21** The cornea and lens in your eye bend light rays so that a sharp image is formed on the retina.



### **Experimenting with Focal Lengths**

#### Procedure Procedure

- **1.** Complete the safety form.
- 2. Fill a glass test tube with water and seal it with a lid or stopper.
- **3.** Type or print *SULFUR* **DIOXIDE** in capital letters on a piece of paper.
- 4. Set the test tube horizontally over the words. Record your observations.
- **5.** Hold the tube at several heights above the words. Record your observations.

#### **Analysis**

- **1.** Describe how the words changed as the height of the test tube increased.
- **2.** Classify the image at each height as real or virtual.

**Figure 22** Farsightedness can be corrected by convex lenses.

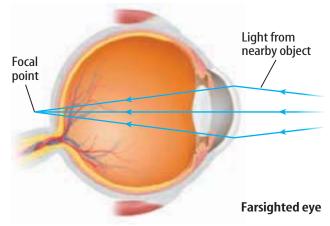
**Brightness and Intensity** The human eye can adjust to the brightness of the light that strikes it. If you step outside on a sunny day, you may have to shade your eyes against the intensity of the sunlight. Light intensity is the amount of light energy that strikes a certain area each second. Brightness is the human perception of light intensity. Sunlight seems bright because a large amount of light energy strikes your retina each second. Your eyes respond to bright light by decreasing the size of your pupil. This reduces the amount of light that enters your eye and strikes the retina.

Intensity depends on your distance from a light source. If you move away from a bare lightbulb, you can see how the intensity of the light rapidly decreases. Because light rays spread out from the source, less light energy strikes your retina the farther away you are from the bulb.

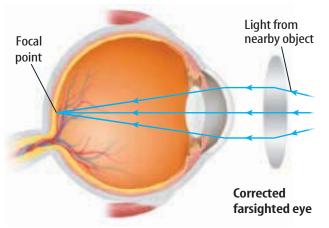
## **Correcting Vision Problems**

If you have good vision, you should be able to see objects clearly when they are 25 cm or farther away from your eyes. A sharp image of an object should be formed on your retina. However, for many people, the image is blurry or formed in the wrong place, causing vision problems.

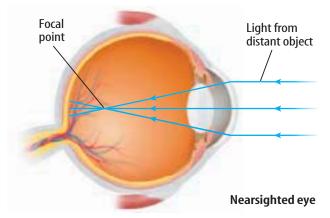
**Farsightedness** If you can see distant objects clearly but can't bring nearby objects into focus, then you are farsighted. In this case, the eyeball might be too short or the lens isn't curved enough to form a sharp image of nearby objects on the retina, as shown in Figure 22. To correct the problem, convex lenses can be used to bend incoming light rays so they converge before they enter the eye.



The focal length of a farsighted eye is too long to form a sharp image of nearby objects on the retina.



A convex lens in front of a farsighted eye enables a sharp image of nearby objects to be formed on the retina.



When a nearsighted person looks at distant objects, a sharp image is formed in front of the retina.

Light from Focal distant object point Corrected nearsighted eye

A concave lens in front of a nearsighted eye makes light rays diverge so a sharp image is formed on the retina.

**Nearsightedness** If you have nearsighted friends, you know that they can see only nearby objects clearly. Their eyes cannot form a sharp image on the retina of an object that is far away. Instead, the image is formed in front of the retina, as shown in Figure 23. To correct this problem, a nearsighted person can wear concave lenses. **Figure 23** shows how a concave lens causes incoming light rays from distant objects to diverge before they reach the eye. Then the rays can be focused by the eye to form a sharp image on the retina.

**Figure 23** Nearsightedness can be corrected with concave lenses.

## section

## Summary

## review

#### Self Check

#### **Mirrors**

- A plane mirror forms upright, virtual images.
- The image formed by a concave mirror depends on the location of the object relative to the focal point.
- Convex mirrors always produce virtual, upright images that are smaller than the object.

- The image formed by a convex lens depends on the distance of the object from the lens.
- Concave lenses always form virtual, upright images that are smaller than the object.

#### The Eye and Vision

- The eye contains a lens that changes shape to produce sharp images on the retina.
- Farsightedness occurs when the eye cannot form a sharp image of nearby objects. Nearsightedness occurs when the eye cannot form sharp images of distant objects.

- 1. **Diagram** how light rays from an object are reflected by a convex mirror to form an image.
- 2. Infer how the size of the image changes if an object that is less than one focal length from a concave mirror moves closer to the mirror.
- **3. Explain** how the focal length of a convex lens changes as the sides of the lens become less curved.
- **4. Compare** the image of an object less than one focal length from a convex lens with the image of an object more than two focal lengths from the lens.
- **5. Think Critically** Describe the image formed by a light source placed at the focal point of a convex lens.

## **Applying Math**

6. Calculate Object Distance If you looked through a convex lens with a focal length of 15 cm and saw a real, inverted, enlarged image, what is the maximum distance between the lens and the object?



# REFLECTIONS OF REFLECTIONS

How can you see the back of your head? You can use two mirrors to view a reflection of a reflection of the back of your head.



How many images are seen in two mirrors?

#### Goal

■ **Infer** how the number of images depends on the angle between two mirrors.

#### **Materials**

plane mirrors (2) protractor masking tape paper clip

#### Safety Precautions 🖚 🗪 🕼

Handle glass mirrors and paper clips carefully.

#### Procedure

- 1. Complete the safety form.
- **2.** Lay one mirror on top of the other with the mirror surfaces together. Tape together one side so they can open and close. Use tape to label them *L* and *R* for *left* and *right*.
- **3.** Open the mirrors and stand them on a sheet of paper at an angle of 72°.

Images and Wedges Seen in the Mirrors			
Angle of Mirrors	Number of Paper Clip Images		Number
OI MITTOTS	R	L	of Wedges
72°			
900	Do not writ	e in this bo	ook.
120°			



- **4.** Bend one leg of a paper clip up 90° and place it close to the front of the *R* mirror.
- **5.** Count the number of images of the paper clip you see in the R and L mirrors. Record these numbers in your data table.
- **6.** The mirrors create an image of a circle divided into wedges. Record the number of wedges.
- **7.** Hold the *R* mirror still and slowly move the *L* mirror to 90°. Record the numbers of images of the clip and wedges in the circle. Repeat, this time opening the mirrors to 120°.

#### Conclude and Apply

- **1. Infer** the relationship between the number of wedges and paper clip images.
- **2. Determine** the angle that would divide a circle into six wedges. Hypothesize how many images would be produced. Test your hypothesis.



Demonstrate for younger students the relationship between the angle of the mirrors and the number of reflections.



# **Light and Color**

#### **Reading Guide**

#### *What* You'll Learn

- **Explain** how you see color.
- **Describe** the difference between light color and pigment color.
- Predict what happens when different colors are mixed.

#### Why It's Important

From traffic lights to great works of art, color is an important part of your world.

#### Review Vocabulary

retina: inner layer of the eye containing cells that convert light images into electrical signals

#### **New Vocabulary**

pigment

#### **Why Objects Have Color**

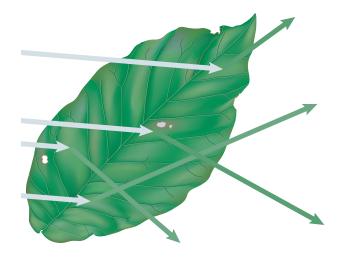
Why do some apples appear red, while others look green or yellow? An object's color depends on the wavelengths of light it reflects. Recall that white light is a blend of all colors of visible light. When a red apple is struck by white light, it reflects red light back to your eyes and absorbs all of the other colors. **Figure 24** shows white light striking a green leaf. Only the wavelengths corresponding to green light are reflected to your eyes.

Although some objects appear to be black, black isn't a color. Black is the absence of visible light. Objects that appear black absorb all colors of light and reflect little or no light back to your eyes. White objects appear to be white because they reflect all colors of visible light.

Reading Check Why does a white object appear white?

**Colored Filters** Wearing tinted glasses changes the color of almost everything you see. If the lenses are yellow, the world takes on a golden glow. If they are rose colored, everything looks rosy. Something similar would occur if you placed a colored, clear plastic sheet over this white page. The paper would appear to be the same color as the plastic. The plastic sheet and the tinted lenses are filters. A filter is a transparent material that transmits one or more colors of light but absorbs all others. The color of a filter is the color of the light that it transmits.

**Figure 24** This leaf absorbs all wavelengths of visible light except the wavelengths you see as green.





**Figure 25** The color of this cooler changes when viewed through different color filters.





**Looking Through Colored Filters Figure 25** shows how the color of an object can change when you look at it through various colored filters. The cooler looks blue under white light because it reflects only the wavelengths of blue light that strike it. If you look at the cooler through a blue filter, the cooler still looks blue because the blue filter transmits the reflected blue light. However, if you look at the cooler through a red filter, the cooler seems black because the red filter blocks the blue light reflected by the cooler.



Why does a blue object appear black when viewed through a red filter?

#### **Seeing Color**

As you approach a busy intersection, the color of the traffic light changes from green to yellow to red. On the cross street, the color changes from red to green. At a busy intersection, traffic safety depends on your ability to detect color changes rapidly. How do you see colors?

**Light and the Eye** In a healthy eye, light enters the eye through the cornea, is focused by the lens, and finally forms an image on the retina. The retina is made up of two types of cells that absorb light, as shown in **Figure 26.** When these cells absorb light energy, chemical reactions convert light energy into nerve impulses that are transmitted to the brain. One type of cell in the retina, called a cone, enables you to distinguish colors and detailed shapes of objects. Cones need bright light to generate nerve impulses, so they do not operate in dim light. As a result, even brightly colored objects might look gray or black in dim light.



Visit **gpescience.com** for Web links to information about the causes of color blindness.

**Activity** Research the causes and types of color blindness. Find out how cones are related to the ability to distinguish colors.

**Figure 26** Light enters the eye Rod and focuses on the retina. The two types of light-detecting cells that make up the retina are called rods and cones. Cone Retina

**Cones and Rods** Your eyes have three types of cones, each of which responds to a different range of wavelengths. Red cones respond to mostly red and yellow light. Green cones respond to mostly yellow and green light. Blue cones respond to mostly blue and violet light. The second type of cell in the retina, called a rod, is sensitive to dim light and enables you to see at night. However, rod cells do not enable you to see colors.

**Interpreting Color** Why does a banana

look yellow? The light reflected by the banana causes the cone cells that are sensitive to red and green light to send signals to your brain. Your brain could get the same signal if a mixture of red light and green light reached your eyes. This mixture also would cause your red and green cones to respond, and you would see the color yellow. As a result, light with wavelengths corresponding to yellow light and light that is a mixture of red and green light both cause the color yellow to be seen. What happens when you look at a white shirt? You see white when all wavelengths of visible light enters your eyes. Then all three sets of cones cells send signals to the brain. The combination of these signals cause you to see the shirt as white.

**Color Blindness** If one or more of your sets of cone cells do not function properly, you might not be able to distinguish certain colors. This condition is called color blindness or color deficiency. About eight percent of men and one-half percent of women have some form of color blindness. The most common form of color blindness makes it difficult to distinguish between red and green. Figure 27 shows an image that is used in a test for red-green color blindness. Because red and green are used in traffic signals, drivers and pedestrians must be able to identify them.

Figure 27 Color blindness is an inherited sex-linked condition in which certain sets of cones in the retina do not function properly. **Identify** the number that you see in the dots.





Color for Photosynthesis Plant pigments determine the wavelengths of light for photosynthesis. Leaves usually look green because of the pigment chlorophyll. Chlorophyll absorbs most wavelengths of visible light except green, which it reflects. However, not all plants are green. Research different plant pigments to find out how they allow plant species to survive in diverse habitats.

#### **Mixing Colors**

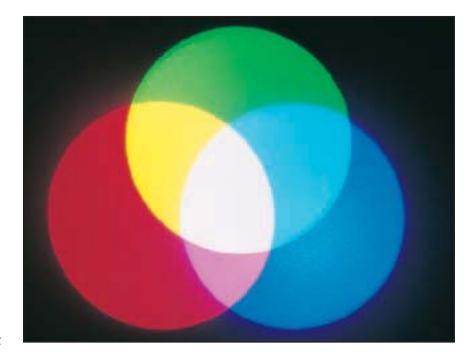
If you have ever browsed through a paint store, you have probably seen displays where customers can select paint samples of almost every imaginable color. The colors are a result of mixtures of pigments. For example, you might have mixed blue and yellow paint to produce green paint. A pigment is a colored material that is used to change the color of other substances. The color of a pigment results from the different wavelengths of light that the pigment reflects.

**Mixing Colored Lights** From the glowing orange of a sunset to the deep blue of a mountain lake, all the colors you see can be made by mixing three colors of light. These three colors red, green, and blue—are the primary colors of light. They correspond to the three different types of cones in the retina of your eye. When mixed together in equal amounts, they produce white light, as Figure 28 shows. Mixing the primary colors in different proportions can produce the colors you see.

Reading Check What are the primary colors of light?

**Paint Pigments** If you were to mix equal amounts of red, green, and blue paint, would you get white paint? If mixing colors of paint were like mixing colors of light, you would, but mixing paint is different. Paints are made with pigments. Pigments produce color as a result of the wavelengths of light they reflect. Paint pigments usually are made of chemical compounds such as titanium oxide, a bright white pigment, and lead chromate, which is used for painting yellow lines on highways.

Figure 28 White light is produced when the three primary colors of light are mixed in equal amounts.



**Mixing Pigments** You can make any pigment color by mixing different amounts of the three primary pigments-magenta (bluish red), cyan (greenish blue), and yellow. In fact, color printers use these pigments, as well as black ink, to make full-color prints like the pages in this book. A primary pigment's color depends on the wavelengths of the light that it reflects. Actually, pigments both absorb and reflect a range of colors in sending a single color message to your eye. For example, in white light, yellow pigment appears yellow because it reflects red and green light but absorbs the other wavelengths of visible light. The color of a mixture of two primary pigments is determined by the primary colors of light that both pigments reflect.

Look at **Figure 29.** The area in the center where the colors all overlap appears to be black because the three blended primary pigments absorb all the primary colors of light. Recall that the primary colors of light combine to produce white light. They are called additive colors. However, when the primary pigment colors are combined, they absorb all wavelengths of visible light and produce black. Because black results from the absence of reflected light, the primary pigments are called subtractive colors.



**Figure 29** The three primary pigment colors appear to be black when they are mixed. **Describe** how the primary pigment colors are similar to the primary col-

#### section геуіеш

#### **Summary**

#### **Why Objects Have Color**

- The color of an object is determined by the wavelengths of light it reflects.
- The color of a filter is the color of the light the filter transmits.

#### **Seeing Color**

- Rod and cone cells are light-sensitive cells found in the retina of the human eye.
- Rod cells are sensitive to dim light. Cone cells enable colors to be seen.
- There are three types of cone cells. One type responds to red light, another to green light, and another to blue light.

#### **Mixing Colors**

- Red, green, and blue are the primary light colors. Any color of light can be created by mixing these primary light colors.
- Any pigment color can be formed by mixing the primary pigment colors—magenta, cyan, and yellow.

#### **Self Check**

ors of light.

- 1. Identity what colors are reflected and what colors are absorbed if a white light shines on a red shirt.
- 2. Discuss how the primary colors of light differ from the primary pigment colors.
- 3. Explain why a red apple would appear black if you looked at it through a blue filter.
- **4. Determine** why a white fence appears to be white instead of multicolored if all colors are present in white light.
- **5. Think Critically** Light reflected from an object passes through a green filter, then a red filter, and finally a blue filter. What color will the object seem to be?

#### **Applying Math**

- **6. Use Percentages** In the human eye there are about 120,000,000 rods. If 90,000,000 rods trigger at once, what percentage of the total number of rods triggered?
- **7. Convert Units** The wavelengths of light are measured in nanometers (nm) which equals 0.000001 mm. Find the wavelength in mm of a light wave that has a wavelength of 690 nm.



#### **Design Your Own**

# Blocking Noise Pallutian

#### Goals

- **Design** an experiment that tests the effectiveness of various types of barriers and materials for blocking out noise pollution.
- **Test** different types of materials and barriers to determine the best noise blocks.

#### **Possible Materials**

radio, CD player, horn, drum, or other loud noise source shrubs, trees, concrete walls, brick walls, stone walls, wooden fences, parked cars, or hanging laundry sound meter meterstick or metric tape

measure

#### Real-World Problem

What loud noises do you enjoy, and which ones do you find annoying? Most people enjoy a music concert performed by their favorite artist, or the booming displays of fireworks on the Fourth of July. Most people enjoy these loud sounds for short periods of time. However, certain other loud noises, such as traffic, sirens, and loud talking, can be annoying. Constant, annoying noises are called noise pollution. What can be done to reduce noise pollution? What types of barriers will best block out noise pollution?

#### Form a Hypothesis

Based on your experiences with loud noises, form a hypothesis that predicts the effectiveness of different types of barriers at blocking out noise pollution.

#### Test Your Hypothesis

#### Make a Plan

- 1. Complete the safety form.
- **2. Decide** what type of barriers or materials you will test.
- **3. Describe** exactly how you will use these materials.



# Using Scientific Methods

- **4. Identify** the controls and variables you will use in your experiment.
- **5. List** the steps you will use and describe each step precisely.
- Prepare a data table in your Science Journal to record your measurements.
- 7. Organize the steps of your experiment in logical order.

#### **Follow Your Plan**

- Ask your teacher to approve your plan and data table before you start.
- 2. Conduct your experiment as planned.
- 3. Test each barrier two or three times.
- **4. Record** the results from each test in your data table in your Science Journal.

#### Analyze Your Data-

- 1. **Identify** the barriers that most effectively reduced noise pollution.
- 2. **Identify** the barriers that least effectively reduced noise pollution.
- **3. Compare** the effective barriers and identify common characteristics that might explain why they reduced noise pollution.
- **4. Compare** the natural barriers you tested with the artificial barriers. Which type of barrier best reduced noise pollution?
- **5. Compare** the different types of materials the barriers were made of. Which type of material best reduced noise pollution?

#### Conclude and Apply

- 1. **Evaluate** whether your results support your hypothesis.
- 2. **Predict** how your results would differ if you used a louder source of noise such as a siren.
- **3. Infer** from your results how people living near a busy street could reduce noise pollution.
- 4. Identify major sources of noise pollution in or near your home. How could they be reduced?
- **5. Research** how noise pollution can be unhealthy.





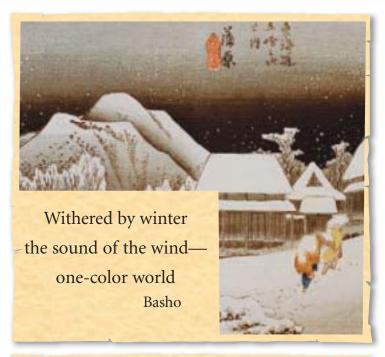
Draw a poster illustrating how builders and landscapers could use certain materials to better insulate a home or office from excess noise pollution.

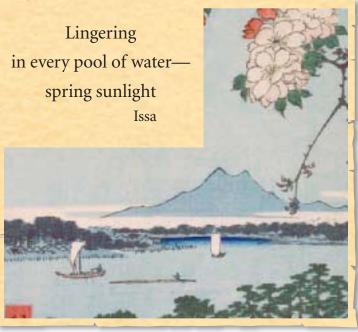
# Science Language

# A Haiku Garden:

The Four Seasons in Poems and Prints

by Stephen Addiss with Fumiko and Akira Yamamoto



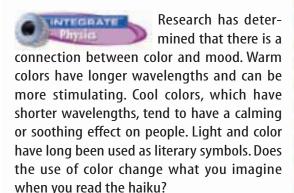


#### **Understanding** Literature

Japanese Haiku A haiku is a verse that consists of three lines and 17 syllables in the Japanese language. The first and third lines have five syllables each, and the middle line has seven syllables. Why is imagination important in reading haiku?

#### Respond to the Reading

- 1. How do the illustrations help the reader better understand the poems?
- 2. What do you think is meant by the word *lingering* in the Haiku about spring sunlight?
- 3. Linking Science and Writing Write one haiku about summer and another about fall. In one poem, use color to help you describe the season. In the other, use light or some property of light to help describe the season.



#### **Reviewing Main Ideas**

#### Section 1 Sound

- **1.** Sound waves are compressional waves that travel only in matter.
- **2.** The speed of sound in a material depends on the type of material as well as its temperature.
- 3. Loudness depends on a sound wave's intensity. Pitch depends on a sound wave's frequency.
- **4.** Sound waves are used in echolocation, sonar, and medical imaging.

#### Section 2

#### **Reflection and Refraction** of Light

- 1. Light can be absorbed, reflected, or transmitted by a material.
- **2.** When light waves are reflected, they obey the law of reflection—the angle of incidence equals the angle of reflection.



**3.** A light wave is refracted, or bent, when it changes speed as it travels at an angle from one material to another.



#### Section 3

#### Mirrors, Lenses, and the Eye

- **1.** Plane mirrors form upright, virtual images.
- **2.** Images formed by concave mirrors and convex lenses depend on the location of the object relative to the focal point.
- **3.** Convex mirrors and concave lenses form virtual, upright images that are smaller than the object.
- **4.** The lens in the human eye changes shape to produce a sharp image on the retina.

#### Section 4

#### Light and Color

- **1.** You see color when light is reflected off objects and into your eyes.
- **2.** Cone cells in the retina are light-sensitive cells that enable you to distinguish colors.
- **3.** Red, blue, and green are the three primary colors of light and can be mixed to form all other colors.
- **4.** The primary pigment colors are magenta, cyan, and yellow.

FOLDABLES Use the Foldable you made at the beginning of the chapter to help you review sound and light.

#### **Using Vocabulary**

concave lens p. 335 loudness p. 322 opaque p. 327 opaque p. 327 opaque p. 327 opaque p. 342 opaque p

Complete each statement with the correct vocabulary word or phrase.

- **1.** A change in frequency due to a moving sound source is due to the \_\_\_\_\_.
- **2.** A flat, smooth surface that reflects light and forms an image is a(n) \_\_\_\_\_.
- **3.** An object is \_\_\_\_\_\_ if you can see through it clearly.
- **4.** The \_\_\_\_\_\_ of a material indicates how much the speed of light in the material changes as light passes through.
- **5.** You can change the color of white paint by adding a(n) \_\_\_\_\_ to it.
- **6.** A(n) \_\_\_\_\_\_ is a reflecting surface that curves outward like the back of a spoon.
- **7.** The human perception of the intensity of a sound wave is \_\_\_\_\_\_.

#### **Checking Concepts**

Choose the word or phrase that best answers each question.

- **8.** Which of the following best describes image formation by a plane mirror?
  - **A)** A real image is formed in front of the mirror.
  - **B)** A real image is formed behind the mirror.
  - **C)** A virtual image is formed in front of the mirror.
  - **D)** A virtual image is formed behind the mirror.

- **9.** For a sound with low pitch, what else is also always low?
  - A) amplitude
- **C)** wavelength
- **B)** frequency
- **D)** wave velocity
- **10.** Which of the following occurs when a sound source moves away from you?
  - **A)** The sound's velocity decreases.
  - **B)** The sound's loudness increases.
  - **C)** The sound's frequency decreases.
  - **D)** The sound's frequency increases.

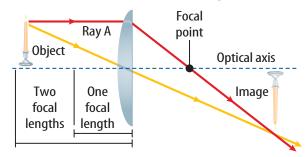
Use the table below to answer question 11.

Speed of Sound in Air		
Temperature (°C)	Sound Speed (m/s)	
0	331.4	
10	337.4	
20	343.4	

- **11.** Based on the data in the table above, which of the following would be the speed of sound in air at 30°C?
  - **A)** 340.4 m/s
- **c)** 349.4 m/s
- **B)** 346.4 m/s
- **D)** 353.4 m/s
- **12.** What happens to a light ray traveling parallel to the optical axis of a convex lens that passes through the lens?
  - A) It travels parallel to the optical axis.
  - **B)** It passes through the focal point.
  - **c)** It is bent away from the optical axis.
  - **D)** It forms a virtual image.
- **13.** Light waves of which color are bent most when passing through a prism?
  - **A)** blue
- **C)** violet
- **B)** red
- **D)** yellow
- **14.** Which way does a concave lens bend light?
  - **A)** toward its optical axis
  - **B)** toward its center
  - **c)** toward its edges
  - **D)** toward its focal point

#### **Interpreting Graphics**

Use the illustration below to answer question 15.



**15. Describe** how the position of the candle changed if the image of the candle moved away from the focal point.

#### **Thinking Critically**

- **16.** Apply Acoustic scientists sometimes do research in rooms that absorb all sound waves. How could such a room be used to study how bats find their food?
- **17. Compare** White light passes through a translucent pane of glass and shines on a shirt. Both the translucent glass and the shirt appear green. Compare the colors of light that are absorbed and transmitted by the glass and the shirt.
- **18.** Infer Most mammals, including dogs and cats, can't see colors. Infer how the retina of a cat's eye might be different from the retina of a human eye.
- **19. Determine** whether a convex lens could form an image that is enlarged, real, and upright.
- **20.** Infer A car comes to a railroad crossing. The driver hears a train's whistle and its pitch becomes lower. What can be assumed about how the train is moving?
- **21.** Compare and contrast the reflection of light from a white wall with a rough surface with the reflection of light from a mirror.

- **22. Infer** why a convex mirror and a concave lens can never produce a real image.
- 23. Predict what color a white shirt would appear to be if the light reflected from the shirt passed through a red filter and then through a green filter.
- **24.** Explain why windows might begin to rattle when an airplane flies overhead.
- **25. Communicate** Some people enjoy using snowmobiles. Others object to the noise that they make. Write a proposal for a policy that seems fair to both groups for the use of snowmobiles in a state park.

#### **Applying Math**

Use the wave speed equation,  $v = f\lambda$ , to answer questions 26 and 27.

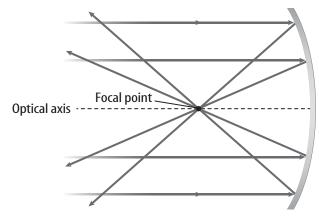
- **26.** Calculate Frequency A sonar pulse has a wavelength of 3.0 cm and a speed in water of 1,500 m/s. Find its frequency.
- **27.** Calculate Wavelength What is the wavelength of a sound wave with a frequency of 440 Hz if the speed of sound in air is 340 m/s?
- **28. Calculate Angle of Incidence** A light ray is reflected from a mirror. If the angle between the incident ray and the reflected ray is 136°, what is the angle of incidence.
- **29. Determine Object Distance** You hold an object in front of a concave mirror with a focal length of 30 cm. If you do not see a reflected image, how far from the mirror is the object?
- **30.** Calculate Speed The speed of light in a vacuum is 300,000 km/s. If the index of refraction of water is 1.33, what is the speed of light in water?

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### Multiple Choice

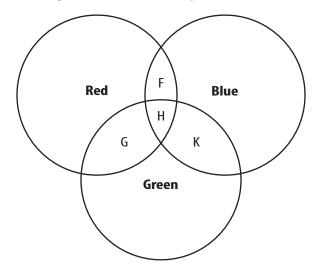
- **1.** Which of the following describes the image formed by a convex mirror?
  - A. enlarged
  - **B.** inverted
  - C. real
  - **D.** virtual

#### Use the figure below to answer question 2.



- **2.** Which of the following describes a light ray that passes through the focal point and then is reflected by the mirror?
  - **A.** It travels parallel to the optical axis.
  - **B.** It forms a real image.
  - **c.** It is reflected back through the focal point.
  - **D.** It forms a virtual image.
- 3. Why does an apple look red?
  - **A.** It reflects red light.
  - **B.** It absorbs red light.
  - **c.** It reflects green and blue light.
  - **D.** It reflects all colors of light except red.

#### Use the figure below to answer questions 4 and 5.

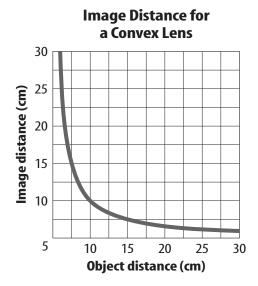


- **4.** When the primary colors of light are added together, what color appears in area H?
  - A. cyan
  - B. magenta
  - **c.** white
  - **D.** yellow
- **5.** When the primary colors of light are added together, what color appears in area *G*?
  - A. cyan
  - B. magenta
  - **c.** white
  - **D.** yellow
- **6.** Which of the following increases as the frequency of a sound increases?
  - A. amplitude
  - **B.** intensity
  - **c.** loudness
  - **D.** pitch

- **7.** Which of the following parts of the eye enable you to see colors in bright light?
  - A. cone cells
  - B. cornea
  - C. lens
  - **D.** rod cells

#### Gridded Response

Use the graph below to answer questions 8 and 9.



- **8.** Determine how far, in centimeters, the image is from the lens when the object is 15 centimeters from the lens.
- **9.** How far, in centimeters, is the object from the lens when the image distance and object distance are equal?

#### Test-Taking Tip

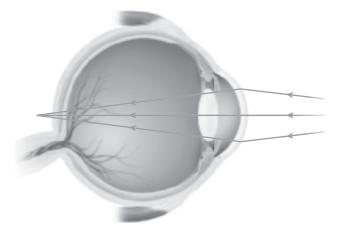
**Note Units** Read carefully and make note of the units used in any measurement.

#### Short Response

- **10.** A shirt has stripes that are black and white in white light. If green light shines on this shirt, what colors will the black and white stripes be?
- **11.** If you are on a moving train, what happens to the pitch of a crossing bell as you approach the crossing and then move away from the crossing?

#### Extended Response

Use the figure below to answer question 12.



- **12.** Describe the vision problem show by the figure and explain how this vision problem can be corrected.
- **13.** Explain why the human eye can see colors better in bright light than in dim light.

#### chapter

# 12

#### BIG (Idea

Plate motion is caused by the movement of thermal energy within Earth.

### 12.1 Evolution of Earth's Crust

MAIN (Idea Earth's surface is made of plates that are slowly moving.

#### 12.2 Earthquakes

MAIN (Idea Earthquakes occur when blocks of rock move along faults.

#### 12.3 Earth's Interior

MAIN (Idea Earth is made of several layers, including the inner core, the outer core, the mantle, and the crust.

#### 12.4 Volcanoes

MAIN (Idea Volcanoes are formed by molten rock that rises to the surface from deep within Earth.

#### Italian Fireworks

Mt. Etna on the Italian island of Sicily is the highest volcano in Europe. Molten rock from deep in Earth is rising through a weak spot in Earth's crust. Mt. Etna began forming about 500,000 years ago. It is one of the most active volcanoes in the world.

#### Science Journal

Research the most recent eruption of Mt. Etna and write a report on how it affected the surrounding environment.

# Earth's Internal **Processes**

#### **Start-Up Activities**



#### **Global Jigsaw Puzzle**

Alfred Wegener, a German scientist, noticed that the shapes of continental coastlines appeared as though they could match up. He suggested that the continents once were together as one giant landmass. Use a map of the world to test this idea. Can you see what he saw?

- **1.** Cut out continents from a copy of a world map provided by your teacher.
- 2. Try to arrange continents so that they fit together.
- 3. Infer why the fit might not be perfect.
- **4. Think Critically** What changes in procedure might demonstrate a better fit for the continents?

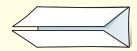


Preview this chapter's content and activities at gpescience.com



**Systems** Make the following Foldable to help you organize information about types of plate boundaries.

Fold one piece of paper lengthwise into thirds.



**STEP 2 Fold** the paper widthwise into fourths.



STEP 3 Unfold, lay the paper lengthwise, and draw lines along the folds. Label your table as shown.

Plate Boundary Type	Description	Illustration
Divergent		
Convergent		
Transform		

Making a Table As you read the chapter, complete the table describing and illustrating divergent, convergent, and transform plate boundaries.

# **Evolution of Earth's Crust**

#### **Reading Guide**

#### What You'll Learn

- **Explain** supporting evidence for the continental drift hypothesis.
- **Discuss** the failings of the continental drift hypothesis.

#### Why It's Important

Wegner's continental drift hypothesis led to a unifying theory of Earth sciences known as plate tectonics.

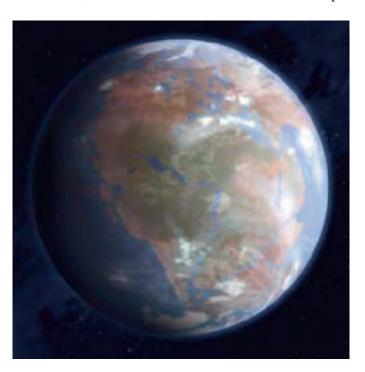
#### Review Vocabulary

hypothesis: statement proposed to explain an observation or answer a question

#### **New Vocabulary**

- mid-ocean ridge
- rift valley
- divergent boundary
- convergent boundary
- subduction
- transform boundary

Figure 1 This illustration is an artist's conception of what Pangaea may have looked like 200 million years ago.



#### **Continental Drift**

In the early twentieth century, there was no single theory of how Earth processes interrelated. Much geologic study was done locally because transportation and communication were expensive. Based upon their observations, geologists developed theo-

> ries that emphasized vertical changes, for example, an erosion process that leveled high places, and a mountain-building process that lifted them up again.

> Then in 1915, Alfred Wegener (VEG nur) proposed a hypothesis that suggested that Earth's continents once were part of a large super-continent, shown in Figure 1, called Pangaea (pan GEE uh). Then, about 200 million years ago, the super-continent broke into pieces that drifted over the surface of Earth like rafts on water. However, this hypothesis of continental drift was not accepted by most other geologists. One reason was that Wegener could not explain how the pieces of Pangaea could move. It wasn't until after his death in 1930, that scientific advances finally justified his hypothesis.

**Matching Coastlines** To prove his hypothesis, Wegener had to provide evidence that the continents were once joined together. Wegener used the analogy of a newspaper that was ripped into pieces. To glue the pieces back together, you had to match up the shapes of the torn edges. You also had to line up the printed words so that they made sense. Wegener argued that the shapes of continents, as well as the rock types, fossils, erosion features, and mountain ranges found on different continents, could be matched up.

Figure 2 Weathering of the continental edges does not affect the continental shelves (light blue).

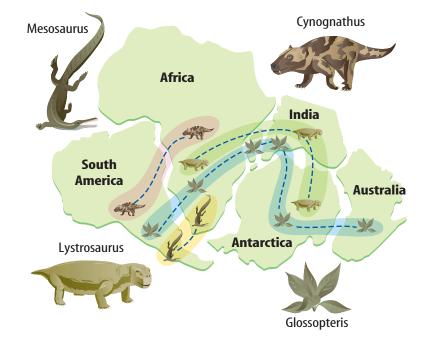
Matching these features on different continents provided evidence that the continents were once joined together where matches occurred.

For example, the eastern coastline of South America fits together with the western coastline of Africa. Also, the coastline of the eastern United States fits together with the northwestern coastline of Africa. If South America and Africa are fitted together, their southern tips together fit the coastline of the Weddell Sea in Antarctica.

Wegener's opponents pointed out that the coastlines are constantly wearing away due to wave action. How could someone compare the present coastlines? Years later, during the revival of the hypothesis, oceanographers were able to show, using sonar, that the edges of the continental shelves matched very well, as shown in Figure 2.

Figure 3 Wegener chose fossils of animals that could not swim or fly to prove Pangaea's existence. **Explain** Why would being able to fly or swim eliminate a fossil organism from Wegener's proof?

Matching Fossils Wegener could not use the remains of just any ancient living thing to support the existence of Pangaea. For instance, animals that could fly or swim could appear in the fossil record in widely separated places due to their mobility, not because the places were necessarily joined. Large land animals provided better evidence because they could not have crossed oceans. Animals such as Lystrosaurus or Cynognathus, large animals that preceded the dinosaurs, supported a contiguous landmass. Glossopteris, a large fern with large, heavy spores also supported the idea of Pangaea. You can see in **Figure 3** that these living things were widely distributed.





**Figure 4** Wegener's hypothesis showed mountains on several continents were once part of the same range.

Matching Rocks and Mountains Mountain ranges were shown to be continuous in Pangaea, as shown in **Figure 4.** Once Pangaea broke apart, the mountain ranges became separated. For decades, geologists studied and attempted to explain the origin of these mountains as separate ranges. Wegener showed them to be one mountain range. Wegener was also able to show that continents that were joined shared unique rocks and minerals.

Wegener's hypothesis was not accepted by his contemporaries because he was unable to conceive of a force or mechanism that could drive continents apart. Wegener reasoned that Earth's rotation, the gravitational pull of the Sun and the Moon, and centrifugal force could move continents. Physicists quickly showed that even combining these forces would not be sufficient.



Why didn't Wegener's contemporaries accept his hypothesis?

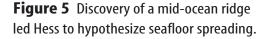
Wegener hypothesized that the continents were moving by pushing through the ocean floor. However, other geologists rejected this idea. They argued that the rock that makes up the ocean floor was too rigid. As a result, oceanic rock would break up, or fracture, if the continents were plowing through it. However, no evidence for this type of fracturing had been found.

#### **Seafloor Spreading Hypothesis**

After World War II, Harry Hess revived Wegener's ideas. He used sonar to obtain accurate maps of the seafloor. Using sonar data, three-dimensional seafloor models were created in 1960.

Hess found a feature called a mid-ocean ridge, or MOR, which was part of all Earth's ocean basins. The MOR system in the Atlantic Ocean is shown in **Figure 5.** 

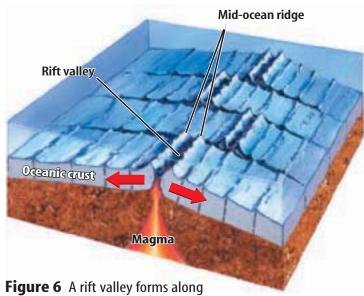
Hess proposed that a MOR is produced by seafloor spreading. He suggested that magma from the mantle is forced upward because of its low density. This causes the crust to crack and move apart. The cracking causes twin mountain ranges with a down-dropped **rift valley** between. This continuous process allows new rock to form as magma fills in from below. This process is shown in **Figure 6.** 





**Ages of Sediment and Rocks** Several types of evidence supported the seafloor spreading hypothesis. One type of evidence was the ages of sediments in cores extracted from the seafloor. Sediment layers near continents are old at the bottom of a core and of recent age at the top. However, sediment layers near an MOR are only of recent age. There are no old sediments near an MOR.

Also, the oldest rocks on continents are almost four billion years old. Rock samples of the seafloor are much younger—most are less than 200 million years old. This difference in age can be explained if rocks of the oceanic crust are continually being formed at an MOR.



the mid-ocean ridge as plates diverge.

#### **Applying Math**

#### **Solve One-Step Equations**

SPREADING DISTANCES The spreading rate along the mid-ocean ridge varies. In the Atlantic Ocean, it averages about 2.5 cm/year. About how far, in kilometers, would the Atlantic seafloor have widened after 100 million years?

#### **IDENTIFY** known values and unknown values

#### Identify the known values:

time = 100,000,000 years

spreading rate = 2.5 cm/year

#### Identify the unknown values:

spreading distance

#### SOLVE the problem

Substitute the known values into the equation:

 $distance = rate \times time$ 

distance =  $2.5 \text{ cm/year} \times 100,000,000 \text{ years} = 250,000,000 \text{ cm}$ 

 $1 \text{ km}/100,000 \text{ cm} \times 250,000,000 \text{ cm} = 2,500 \text{ km}$ 

#### CHECK the answer

Does your answer seem reasonable? How wide is the Atlantic Ocean?

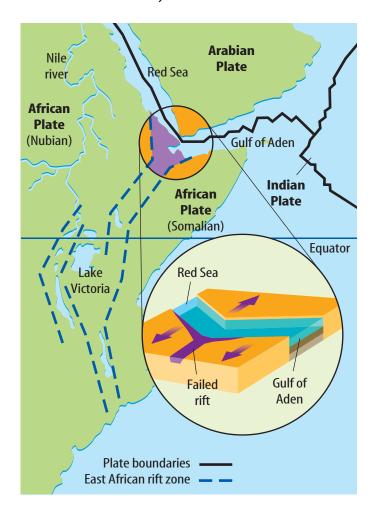
#### **Practice Problems**

If the East Pacific Rise spreads at 12 cm/year, how wide will it be in 10 million years? For more practice problems, go to page 879 and visit Math Practice at gpescience.com.



Sonar In the process of refining sonar's capabilities, discoveries were made that had peacetime benefits. For example, sonar often is equipped on boats to locate schools of fish. A related technique called ultrasound is used in medicine. Research current uses and applications of sonar and ultrasound.

Figure 7 Large lakes and volcanic mountains are characteristics of a continental rift valley.



**Magnetic Polarity of Rocks** More evidence supporting the seafloor spreading hypothesis comes from the study of the magnetic properties of seafloor rocks. Some types of rocks are made of minerals containing iron. When these rocks form, the minerals behave like compass needles and become oriented along Earth's magnetic field. When the rocks harden, this magnetic orientation, or polarity, is locked into place.

Studies show that Earth's magnetic field has reversed direction many times. Rocks that form when Earth's magnetic field was in opposite directions have opposite polarities. On the seafloor, researchers have found bands of rock with alternating polarities, extending out from an MOR. These bands, called magnetic stripes, result when Earth's magnetic field flips as new seafloor rock is continually being formed at an MOR.

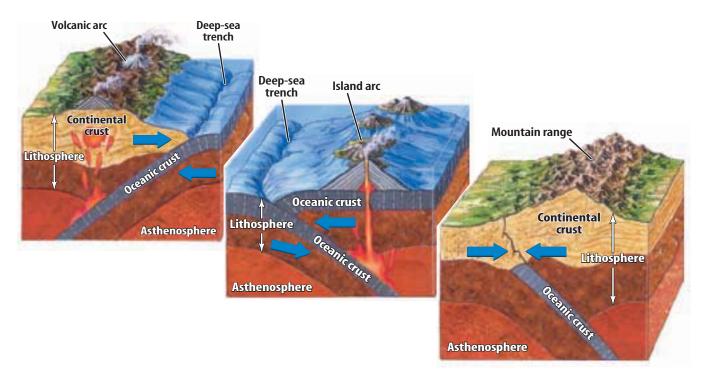
#### **Theory of Plate Tectonics**

In the 1960s geological data led to the development of the theory of plate tectonics. According to the theory of plate tectonics, Earth's surface is made of separate slabs called plates

> that move slowly over Earth's upper layers. The bottom part of a plate is made of a rigid layer of Earth's mantle. The top part of a plate is made of continental crust, oceanic crust, or both.

> As plates move, they interact with each other at their boundaries. There are three main kinds of plate motions. Plates can move apart, move together, or slide past one another. These three types of motion result in three types of plate boundaries divergent plate boundaries, convergent plate boundaries, and transform plate boundaries. Different geological features are produced as plates interact at the different types of boundaries.

> **Divergent Plate Boundaries** At a midocean ridge (MOR), two plates move apart. The boundary between two plates that are moving apart is a divergent boundary. At a divergent boundary, magma rises between the plates, spreads out, and cools to form new oceanic crust. An MOR is a divergent boundary. In some places, divergent boundaries exist as rift valleys, such as in East Africa, shown in **Figure 7.**



**Convergent Plate Boundaries** Where plates come together, they collide to form convergent boundaries. In some cases, a less-dense, thick continental plate moves toward a denser, thin oceanic plate. This results in the oceanic side bending and being forced downward beneath the continental slab in a process called **subduction**. Heat deep in a subduction zone partially melts rock and produces magma, which rises toward the surface. This magma produces a volcanic arc that parallels this zone, shown in **Figure 8.** The boundary also has a deep-sea trench that parallels the zone. The Andes mountain range in South America has been produced by this boundary type.

Convergent plate boundaries also occur where two oceanic plates collide. In this case, the oceanic plate that is colder, and therefore denser, subducts. Magma erupted here produces chains of volcanic islands called island arcs. Japan is an example of an ocean-ocean convergent boundary, also shown in **Figure 8.** The collision of two plates at a convergent boundary can also produce earthquakes that can cause tsunamis.

Along some convergent plate boundaries, two continental plates of low density collide and tend not to subduct. Because of this resistance to subduction, the plates collide and buckle upward to form a high range of folded mountains. Volcanic activity is noticeably absent and there is no trench. The Himalaya of Asia are an example of folded mountains that occur where two continental plates collide.



What is formed when two continental plates converge?

Figure 8 When plates collide, the more dense plate is subducted. The resulting features include volcanoes, mountains, and deep trenches.



#### **Topic: Tsunamis**

Visit gpescience.com for Web links to information about tsunamis.

**Activity** Research the most recent tsunami and its destruction. Record the epicenter and magnitude of the earthquake that caused the tsunami and post these data on a world map. Write a short report that describes the tsunami's impact on humans and the environment.



**Figure 9** Friction between plates moving side by side causes cracks and breaks in the edges of the plates. This is the site of brief, but rapid energy release called an earthquake.

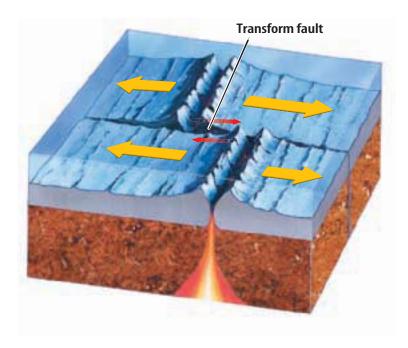
**Transform Plate Boundaries** Some plate boundary zones have large faults, or cracks, along which mostly horizontal movement is taking place, as shown in **Figure 9.** In this case, no new rock is forming, as along a divergent boundary. In addition, old rock is not being recycled, as along a subduction zone. The main result of **transform boundaries** is the horizontal motion of two plates past each other. The San Andreas fault zone is an example of a transform boundary.

Transform faults are extremely important where they cut perpendicular to the MOR. These fault systems allow movement away from ridge crests to occur, as shown in **Figure 10.** If you observe arrows that indicate net motion along these faults, you will notice that this net motion trends away from the MOR.

#### What drives the plates?

Plate motion is caused by a combination of forces. One such force is called ridge push and occurs at an MOR. Because divergent boundaries are higher at the center of the ridge, gravity forces material down the slopes of the MOR.

When plate subduction occurs at a convergent boundary, a force called slab pull is thought to operate. You probably have experienced an analogy to slab pull when you found your bed covers on the floor in the morning. During the night, as you tossed and turned, the covers began to move off of the bed. Eventually, enough of the covers were over the side that gravity took over and pulled the rest of the covers to the floor. Subducting plates may act in much the same way, as portions of descending plates are pulling the rest of a plate down with them.



**Figure 10** A transform fault cuts through the MOR, offsetting the mountain range.

**Frictional Forces** Friction between a plate and mantle material below the plate probably has a major effect on plate motion. For example, plates that drag continental material along with them are noticeably slower than are purely oceanic plates. Scientists think that continental lithosphere has deep roots that cause more frictional force than would be expected at the base of oceanic lithosphere.

Reading Check What role does friction play in plate motion?

**Thermal Energy** Internal convection of mantle material is the driving force for all mechanisms of plate motion. In turn, the main source of thermal energy that keeps Earth materials convecting comes from the decay of radioactive elements in Earth. Increased temperature due to pressure and frictional heating produced as part of the mechanism itself probably are important. Another source of energy is thermal energy left over from the formation of Earth.

#### section

#### review

#### **Summary**

#### **Continental Drift**

- Wegener proposed that former supercontinent Pangaea broke up into pieces, which drifted to their present positions.
- Evidence favoring continental drift includes matching shorelines of continents and correlating rocks, fossils, and mountain ranges of those continents.

#### **Seafloor Spreading Hypothesis**

- Hess suggested that seafloor was created and spread apart at the mid-ocean ridge.
- Moving away from the MOR, rocks are older and sediments are thicker.
- Reversals in Earth's magnetic field produce magnetic stripes of alternating polarity extending out from an MOR.

#### **Theory of Plate Tectonics**

- Earth's rigid, outermost layers are composed of a dozen or so major plates and many smaller ones.
- New lithosphere is created at the MOR and recycled at convergent boundaries. Convective flow within the mantle drives the plates.

#### Self-Check

- 1. Explain the processes of convergence and divergence.
- **2. Describe** the key features of a divergent boundary.
- 3. Compare and contrast the three types of convergent plate boundaries.
- 4. **Describe** the possible driving mechanisms in the plate tectonic theory.
- **5. Think Critically** Predict what would happen if Earth's plates stopped moving.
- **6. Think Critically** What would have to occur to stop Earth's plate movement?

#### **Applying Math**

- 7. If two plates diverge at a rate of 1.3 cm/year, how much farther apart will the plates be after 200 million years?
- **8.** How many times faster are plates moving at 7.3 cm/year than those moving at 1.3 cm/year?
- **9.** The average distance across an ocean is 16,000 km. Two continents on either side of the ocean are converging at a rate of 10 cm/year. How long will it take for them to collide?

# **Earthquakes**

#### **Reading Guide**

#### What You'll Learn

- Describe the causes and characteristics of earthquakes.
- **Explain** how seismic waves affect Earth's surface.
- Describe how seismic waves are used to infer Earth's internal structure.

#### Why It's Important

Earthquakes kill people and destroy property. Understanding earthquakes may help minimize their effects.

#### Review Vocabulary

**friction:** force that opposes the sliding motion between two touching surfaces

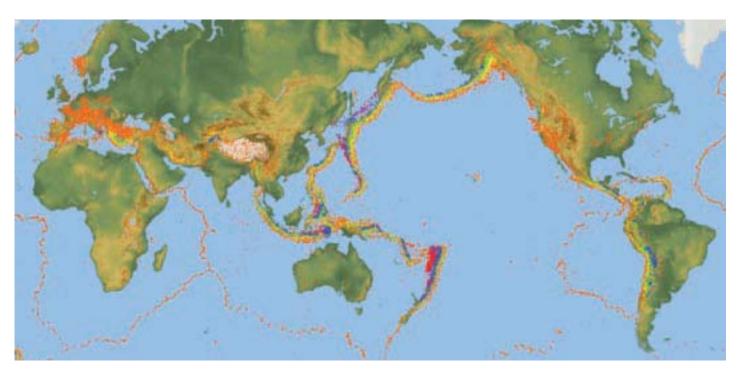
#### **New Vocabulary**

- fault
- elastic rebound
- focus
- epicenter

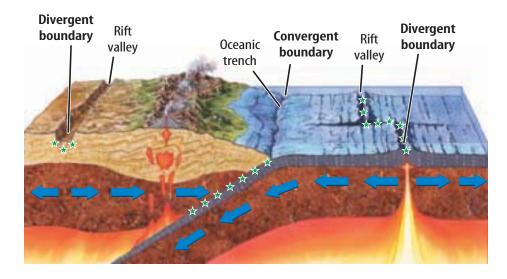
**Figure 11** Most earthquakes occur along the edges of plates. **Identify** some other places earthquakes occur.

#### **Global Earthquake Distribution**

For decades, scientists have known that earthquakes are not distributed randomly. Instead, they usually occur in well-defined zones. The zones where earthquakes occur are the boundaries of Earth's plates. In fact, data from earthquakes helped geologists to understand the structure of Earth's ocean floor and to infer the structure and motion of Earth's plates. **Figure 11** shows the distribution of large earthquakes.



**Earthquake Depth** Depths at which earthquakes occur also provide information about plate boundaries. Earthquakes tend to occur at different depths at different types of plate boundaries. For example, earthquakes near divergent plate boundaries tend to be shallow and occur in a narrow zone, as shown in Figure 12. However, Figure 12 also shows that earthquakes at a convergent plate bound-



ary generally occur at greater depths than those at a divergent boundary. Also, near a convergent boundary, earthquakes occur over a wide zone.

**Causes of Earthquakes** 

An earthquake is the sudden movement or vibration of the ground that occurs when rocks slip along enormous cracks in Earth's crust. The shaking of the ground that occurs during an earthquake can cause buildings to collapse, as shown in **Figure 13.** The collapse of buildings usually causes most of the deaths and injuries that occur during an earthquake.

**Deformation** Earthquakes are caused by forces that act on rocks. A force applied to an object can cause the object to change its shape, or be deformed. The stress on an object is the force per unit area that acts on the object. The strain that occurs when a stress is applied to an object is related to the amount of deformation that occurs. Stresses can be of four types: (1) a

compressive stress, in which an object is squeezed or shortened, (2) a tension stress, in which an object is stretched or lengthened, (3) a shear stress, in which different parts of an object are moved in opposite directions along a plane, or (4) a torsion stress, in which an object is twisted.

Figure 13 This damage was caused when the buildings were shaken off their foundations. **Explain** How might this damage have been prevented?

**Figure 12** The depth at which an earthquake occurs, indicated by the stars, depends on the type of plate boundary. Earthquakes tend to be shallower at a divergent boundary than at a convergent boundary.





#### **Demonstrating Four Types of Stress**

#### **Procedure**

- 1. With palms facing down at all times and your hands in contact with each other, clasp a large bar of taffy with both hands. First, push one hand forward 2 cm while simultaneously pulling the other backward 2 cm. Return your hands to the original position.
- 2. Still holding your hands in contact, twist your hands in opposite directions and return them to the original position.
- 3. Next move your hands about 4 cm apart.
- 4. Finally push your hands back together to the original position.

#### **Analysis**

- 1. Which type of stress did you demonstrate in each of steps 1-4?
- 2. Describe the kinds of deformation you would expect to result from each of the four stresses.

**Elastic Deformation** Elastic deformation occurs when a material deforms as a stress is applied, but snaps back to its origin shape when the stress is removed. Plastic deformation occurs when a material deforms, or changes shape, as a stress is applied and remains in the new shape when the stress is removed. Modeling clay behaves plastically. You might expect rocks to be brittle, which means that they break when the applied stress is large enough. But deep inside Earth, where temperatures are high, rocks deform plastically. For example, you can break off an edge of a wax candle when it is cold and brittle, but the wax bends more under stress—without breaking—when it warms up.

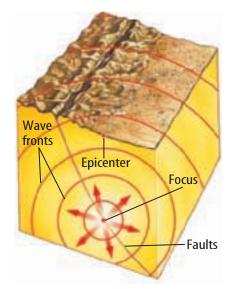
**Energy Release** When an object is deformed, a form of energy called strain energy can be stored in the object. When rock is deformed along cracks in Earth's crust, strain energy builds up in the rock. As this energy is released, the rock moves. A fault is a crack in Earth's crust along which rock has moved. Earthquakes occur when rock that has been stressed releases strain energy and moves along a fault. This sudden release of strain energy when rock moves along a fault is called elastic rebound. Elastic rebound produces waves called seismic waves that travel in Earth. In a similar way, dragging a table across the floor produces a rumbling sound, as the table legs repeatedly stick and then slide.

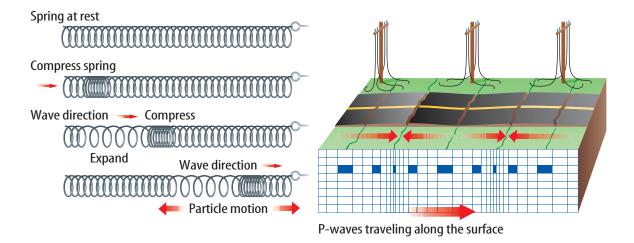
#### **Earthquake Waves**

Seismic waves travel out in all directions from a point where strain energy is released. This point is the focus, or point of origin, of an earthquake. The point on Earth's surface directly above the focus is the epicenter. When you throw a stone into water you see concentric rings of waves move out across the surface from the point of impact. In a similar way, seismic waves move out from the focus in all directions, as shown in Figure 14.

Seismic waves can be sorted broadly into two major types. Body waves travel through Earth. Surface waves travel across Earth's surface.

**Figure 14** The movement of rock along the fault causes an earthquake at the focus. Earthquake waves travel out from the focus in all directions.





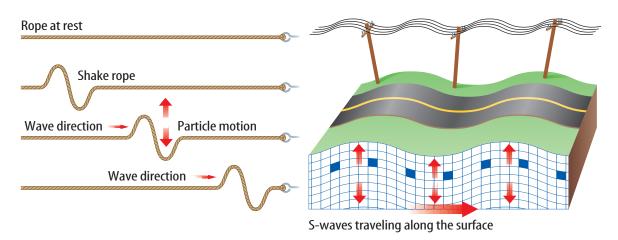
**Primary Waves** One type of body wave is called a primary wave. Primary waves, which are also called P-waves, are like the waves that travel along a coiled spring, as shown in Figure 15. P-waves cause particles in a material to move back and forth along the direction the wave moves. The particles return to their original positions after the wave passes. Just like sound waves, P-waves travel through both solids and liquids. P-waves are the fastest seismic waves. Moving in Earth, their speeds range between 5 km/s and 7 km/s.

**Secondary Waves** Another type of body wave is a secondary wave, which is also called an S-wave. As shown in Figure 16, S-waves are like the waves moving along a rope. S-waves cause the particles in a material to move perpendicular to the direction the wave moves.

S-waves travel through Earth more slowly than P-waves. As a result, S-waves keep getting farther behind P-waves as these waves move farther from the earthquake focus. The time lag between the arrival of the first P-waves and the first S-waves enable the epicenter of an earthquake to be located. Unlike P-waves, S-waves can travel only in solids.

**Figure 15** P-waves cause rock to be compressed and expanded as the wave passes, just like a wave on a spring compresses and expands the coils as it travels. **Describe** How are P-waves like sound waves?

Figure 16 S-waves can cause rock to move up and down perpendicular to the direction in which the wave travels.



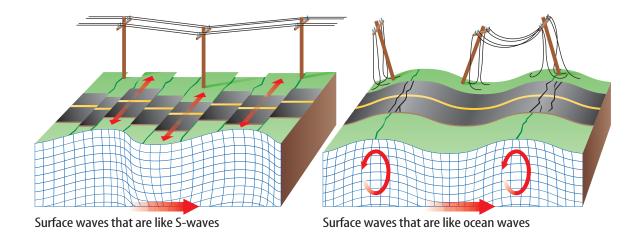


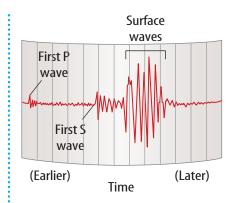
Figure 17 Surface waves produce an up-and-down rolling motion similar to the motion caused by ocean waves. At the same time, the surface can shift from side to side.

**Surface Waves** Surface waves move in a more complex manner, often causing a rolling motion much like ocean waves. As surface waves travel through material, they can exhibit an up and down rolling motion, and also a side-to-side motion that parallels Earth's surface. Foundations of human-built structures often can be damaged by the side-to-side rocking that might result from surface waves. These surface wave motions are illustrated in **Figure 17.** 

Table 1 Estimates of Earthquake Magnitude and Frequency		
Richter Magnitude Range	Description Index	Estimated Occurrence per Year
< 2.0	recorded, but not generally felt	600,000
2.0-2.9	potentially felt	300,000
3.0-3.9	felt by some	49,000
4.0-4.9	felt by most	6200
5.0-5.9	damaging	800
6.0–6.9	destructive in densely populated areas	266
7.0–7.9	potential to inflict major damage	18
8.0 and above	potential to destroy communities near epicenter	1.4

#### **Earthquake Measurement**

Two measurement schemes that have been used to characterize earthquakes are the Modified Mercalli intensity scale and the Richter magnitude scale. The Modified Mercalli scale, shown in **Table 2**, ranks earthquakes according to the amount of damage they cause. The scale ranges from I to XII, with XII being earthquakes that cause the most severe damage. The Richter magnitude scale, which is also called the Richter scale and is shown in **Table 1**, measures the amount of energy released during the earthquake. A device called a seismograph records the vibrations produced by an earthquake. In one type of seismograph, these vibrations cause a pen to move back and forth on a moving sheet of paper. **Figure 18** shows an example of a record produced by this type of seismograph.



**Figure 18** This earthquake record shows the arrival of the first P-wave, then the first S-wave, and then the surface waves.

Table	2 The Mercalli Scale of Earthquake Intensity
Level	Description
- 1	Rarely felt by people.
Ш	Felt by resting people indoors; some hanging objects may swing.
Ш	Felt indoors by several. Vibration like passing of a light truck.
IV	Felt indoors by many. Vibration like passing of a heavy truck. Standing autos rock. Windows, dishes and doors rattle. Walls and frames may creak.
V	Felt by nearly everyone indoors and outdoors. Small unstable objects upset. Some dishes and glassware broken. Swaying of tall objects noticed.
VI	Felt by all. Walking is unsteady, many run outdoors. Windows, dishes, and glassware broken. Furniture overturned and plaster may crack.
VII	Difficult to stand. Noticed by drivers of autos. Furniture and chimneys broken. Well built buildings hardly damaged. Poor structures considerable damage.
VIII	People frightened. Ordinary buildings slightly damaged. Driving of autos affected. Tree limbs fractured. Damage to tall objects. Cracks in wet ground.
IX	General panic. Damage great in substantial buildings. Some houses thrown off foundations. Underground pipes broken. Serious ground cracks.
X	Most masonry and frame structures destroyed. Serious damage to dams, dikes, embankments. Water splashed out of rivers, canals, lakes. Rails bent.
XI	Few structures remain standing. Bridges destroyed. Broad fissures in the ground. Slumps and landslides. Rails bent generally.
XII	Damage nearly total. Waves seen on ground surfaces. Lines of sight and level distorted.  Objects thrown into the air. Large rock masses displaced.

# NATIONAL GEOGRAPHIC VISUALIZING EARTHQUAKE PROOF BUILDINGS

#### Figure 19

ecause the most severe damage from an earthquake is not caused when a structure shakes, but when it falls down, engineers are developing ways to make buildings safer. Their job is to prevent the energy of an earthquake from damaging a building's structure.

What happens when the ground moves back and forth under a building? The first floor moves back and forth, but the energy is not transferred to the whole building. The result is that the bottom of the structure collapses.





One way to keep the building stable is to design a system that allows the whole structure to move as a unit. Base isolation systems use bearings that separate the building from the ground. These bearings can be made of large rubber pads or giant metal springs and are placed between the ground and the building support beams. The stretchy rubber or metal spring absorbs the earthquake energy.



Buildings also can be protected by using structures that can bend. These diagonal braces, called unbonded braces, are made of steel and concrete. The steel beam is shaped so that it can bend back and forth without breaking. The building moves but it does not collapse.



Another way to protect buildings in an earthquake is active damping. Large blocks of metal or concrete, weighing many tons slide back and forth as the building sways. The pendulum motion of the damper absorbs the energy of the earthquake, and reduces the movement of the building.

**368 CHAPTER 12 Earth's Internal Processes** 

**Levels of Destruction** The level of destruction by earthquakes is extremely variable. Research has shown that poor building methods are the largest contributors to earthquake damage and loss of life. In countries where there are poorly constructed buildings, it is not uncommon for tens of thousands of people to die in a single earthquake event. It is possible to use high-technology building methods to make structures earthquake resistant, but not earthquake proof. A large proportion of earthquake damage is secondary, such as damage by landslides, fires, and tsunamis. Active earthquake zones are well established, but predicting precise times for earthquakes in those zones is not yet possible.

**Earthquake Proofing** Although no building can be made entirely earthquake proof, scientists and engineers are finding ways to reduce the damage to structures during mild or moderate earthquakes. Much damage occurs when older structures are shaken off their foundations, so securing a building to its foundation is important. Large masses that can move with the earthquake absorb energy to make a building more secure. Figure 19 shows some other possible methods for reducing the effects of earthquakes and making buildings safer.

#### section

#### review

#### **Summary**

#### **Global Earthquake Distribution**

 The majority of earthquakes occur at varying depths, and in zones that define the locations of plate boundaries.

#### **Causes of Earthquakes**

• Earthquake waves are the result of elastic rebound along faults.

#### **Earthquake Waves**

- Body waves move throughout Earth.
- Surface waves move along Earth's surface. Their motions cause the majority of earthquake damage.

#### **Earthquake Measurement**

- The Modified Mercalli scale is a subjective damage scale that indicates earthquake intensity.
- The Richter magnitude scale measures amplitudes of waves generated by an earthquake. Energy released by an earthquake are estimated from amplitude data.

#### **Self Check**

- 1. Describe the elastic rebound process.
- 2. Contrast primary and secondary seismic waves.
- 3. Compare and contrast the Richter scale with the Mercalli scale.
- 4. Summarize the patterns of global earthquake distribution.
- 5. Think Critically Why couldn't you use the Mercalli scale to measure an undersea earthquake?

#### **Applying Math**

- **6. Calculate** If a primary earthquake wave travels at a rate of about 6 km/s through continental crust, how long will it take it to reach a seismic station located 1,200 km away?
- **7. Calculate** If the secondary wave travels at 10 km/s to the same station in question 6, how much longer will it take for the secondary wave to arrive after the primary wave?

# Earth's Interior

#### **Reading Guide**

#### What You'll Learn

- **Explain** how geologists infer the structure of Earth's deep interior.
- **Describe** Earth's internal structure and composition.

#### Why It's Important

Using waves to indirectly determine the internal structure of an object has many applications in the sciences and engineering.

#### Review Vocabulary

**refraction:** the bending of a wave as it changes speed in moving from one medium to another

#### **New Vocabulary**

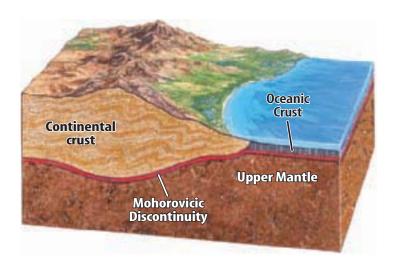
- discontinuity
- shadow zone
- asthenosphere

#### What's inside?

How is it possible to know anything about the interior of Earth? To study Earth's interior, geologists use seismic waves. Their method is similar to the method used by doctors to examine the inside of the human body with ultrasound waves. As they travel in the body, the direction and intensity of these waves are changed by different types of body tissue. By recording these changes, an image of the structures inside the body can be produced.

In a similar way, seismic waves change direction and intensity as they move through different materials inside Earth. By studying how seismic waves are affected as they travel in Earth, geologists can infer the structure of Earth's interior.

Figure 20 The Mohorovicic discontinuity separates Earth's crust from the denser upper mantle. **Infer** why it would be easier to drill through oceanic crust instead of continental crust.



**Refraction** The direction in which seismic waves travel can change when the waves travel from one material into another. Waves usually change speed when they travel from one material into a different material. However, when waves change speed, they can also change direction. Refraction occurs when a change in speed causes a wave to change direction, or bend. The refraction of seismic waves as they pass through Earth provides information about Earth's structure.

#### **Earthquake Observations**

The speed and direction of seismic waves change when the properties of the materials in which they move change. For example, seismic waves are refracted when the density of the material in which they move changes. More refraction occurs as the difference in density increases. The boundary between two layers of material that have different densities is called a discontinuity. A discontinuity known as the Mohorovicic (moh huh ROH vee chich) discontinuity, shown in **Figure 20**, separates Earth's crust from the mantle.

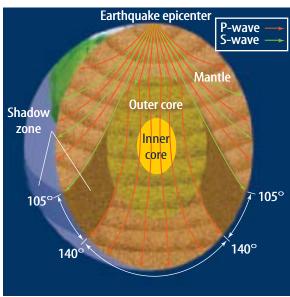
**Shadow Zones** When an earthquake occurs, seismic waves spread out and travel through Earth. Seismographs record the arrival times and shapes of the seismic waves at different places all over Earth. From these data, geologists can infer the paths along which seismic waves travel when they pass through Earth. An example of the paths followed by P-waves and S-waves produced by an earthquake is shown in **Figure 21.** 

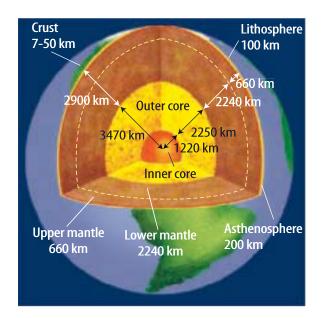
During an earthquake, seismographs over large areas of Earth's surface don't detect any seismic waves. For each earthquake there is a shadow zone, shown in Figure 21, in which there are no seismic waves from the earthquake. This shadow zone occurs for two reasons. One is that P-waves are refracted when they move into and out of the outer and inner cores. This refraction causes the directions of P-waves to bend so that they don't reach the shadow zone.

The other reason the shadow zone occurs is that S-waves do not travel through Earth's outer core. Recall that S-waves can move in solids, but cannot travel in liquids. Because S-waves do not travel in Earth's outer core, geologists have inferred that Earth's outer core is liquid.

**Solid Inner Core** The effects of the inner core on the movement of P-waves show that the inner core is solid. Why is the inner core solid and the outer core liquid? Deep inside Earth, pressures and temperature are very high. High temperatures tend to make Earth materials liquid. High pressures tend to keep Earth materials in a solid state. Over the outer core, temperatures are high enough to overcome the effects of pressure and make the material in the outer core liquid. Over the inner core, the pressure is high enough to overcome the effects of temperature and keep the inner core material solid.

Figure 21 S-waves cannot travel in Earth's liquid outer core, but P-waves pass through the outer core and the solid inner core.





**Figure 22** Layering of Earth is caused by heat and pressure. The most dense materials are at the center and the less dense materials are near the crust.

#### **Composition of Earth's Layers**

Earth's internal layers, illustrated in Figure 22, generally become denser with depth. The crust and uppermost mantle, which together form the lithosphere, are made of rocky material—mostly silicates. The asthenosphere is a weaker, plasticlike layer upon which Earth's lithospheric plates move. Much like the lithosphere, the mantle below the asthenosphere also is composed of silicates. However, the minerals present have different structures in response to conditions of higher pressure. The core layers are made mostly of metallic material, such as iron and nickel, with noticeable amounts of oxygen and sulfur also present. The core apparently has a composition similar to some iron meteorites that have struck Earth throughout its history.

Astronomers hypothesize that early Earth may have formed from meteorite-like material that was forced together by gravity and heated to melting. Some of the material then was able to migrate toward the core. Over billions of years, Earth's matter has melted and separated. The densest materials settled toward the core, and relatively low-density materials floated toward the surface. This separation of materials due to gravity is thought to have taken place in all of the planets.

#### section

#### review

#### **Summary**

#### What's inside?

• Earthquake-generated seismic waves provide information about Earth's deep interior.

#### **Earthquake Observations**

- Earth's interior has a layered structure.
- Changes in density occur at layer boundaries called discontinuities.

#### **Composition of Earth's Layers**

- Earth's layers become denser with depth.
- Layers of crust and mantle are rocky, and composed mainly of silicates.
- The cores have a high density, metallic composition.
- Composition of early Earth closely resembled the composition of meteorites.

#### **Self Check**

- 1. Describe the evidence used for subdividing Earth's interior into layers.
- 2. Explain the following points, using seismic evidence for your argument:
  - a. Earth has a non-uniform density.
  - **b.** Earth has a layered structure.
  - c. Earth has a liquid outer core.
- 3. Compare and contrast the inner and outer cores of Earth.
- **4. Think Critically** Explain why it is impossible to ever really know what materials compose Earth's interior.

#### **Applying Math**

**5. Calculate** What percent of the mantle are the upper mantle, lower mantle, and the asthenosphere?

# **Volcanoes**

#### **Reading Guide**

#### *What* You'll Learn

- **Describe** the types and causes of different types of volcanic eruptions.
- **Explain** the pattern of occurrence of volcanoes and its link to plate tectonics.

#### Why It's Important

Volcanic eruptions have an impact on the composition of the atmosphere and on climate.

#### Review Vocabulary

melting point: temperature at which a solid begins to liquefy

#### **New Vocabulary**

- viscosity
- cinder cone volcano
- shield volcano
- composite volcano

#### **Origin of Magma**

Inside Earth, temperatures are about 1,000°C at depths of around 100 km below the surface and can reach 7,000°C in the inner core. In spite of these high temperatures, most of the rock inside Earth has not melted and is in the solid state. It is the extremely high pressure inside Earth that prevents the rock from melting. Increasing the pressure exerted on a material raises its melting point. Inside Earth, the pressure is so high that at most places the melting point of the rock becomes higher than its temperature.

However, in some places in the asthenosphere, some melting has occurred. Melted rock inside Earth is called magma. Because magma is a liquid, it is less dense than the rock around it. As a result, magma is forced upward until it reaches Earth's surface. As it rises, the pressure on the magma decreases and more melting can occur.

As the magma is forced upward into the lithosphere, it can cause cracks to form in the crust. These cracks provide channels or conduits for the magma to reach the surface, as shown in Figure 23. A volcano is a feature that forms when magma reaches the surface. Magma that has erupted onto Earth's surface is called lava.

**Figure 23** Liquid magma is less dense than the surrounding rock and is forced upward. Magma reaches the surface through cracks in Earth's crust, forming a volcano.

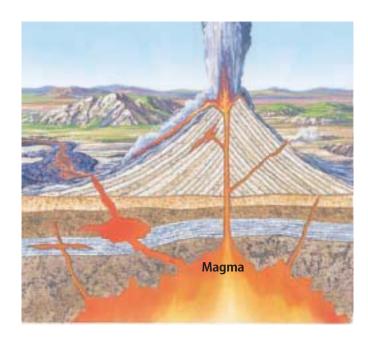
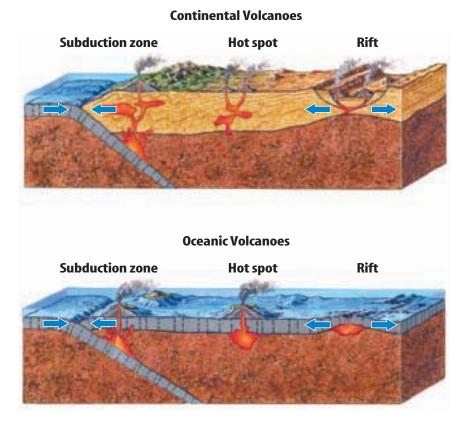


Figure 24 Eruptions of magma commonly occur at subduction zones of convergent plate boundaries, at rifts where plates are separating, and at hot spots.



Where Eruptions Occur Eruptions of magma often occur at hot spots and at plate boundaries, as shown in Figure 24. Hot spots are places in the mantle where the temperature is high enough to form magma. At a converging plate boundary, crustal material is forced downward and melts, forming magma. At a diverging plate boundary, or rift, magma can be forced upward between the separating plates.

## **Eruptive Products**

Volcanic eruptions can expel a variety of materials. These materials include chunks of solid rock, gases, and liquid lava.

**Solids** All solid materials expelled by a volcano are collectively called pyroclasts. Often, lava is ejected into the air as globules. These globules cool and solidify as they fall to Earth. The smallest particles cool very quickly and form volcanic ash. Larger globules form volcanic cinders. There often are chunks of solid rock ripped away from the conduit of the volcano as it erupts. These chunks of rock form volcanic blocks. The larger the size of a pyroclastic particle, the closer it will fall to the volcano. Blocks fall back to ground on a volcano's sides. Ash can be picked up by wind and blown hundreds or even thousands of kilometers away.



**Topic: Huge Eruptions** 

Visit gpescience.com for Web links to information about the world's most powerful volcanic eruptions.

**Activity** In your Science Journal, list information, including dates and locations, of ten of the world's most powerful volcanic eruptions. On a copy of a world map, plot the locations of these events. Is there a pattern to their occurrence in place or in time?

**Gases** Volcanoes release a variety of gases, including water vapor, carbon dioxide, and sulfur dioxide. More water vapor is released than any other gas. The sulfur dioxide can combine with oxygen and water in the atmosphere to form tiny droplets of sulfuric acid. Because these droplets are so small, they take a long time to fall back to Earth's surface. While in the atmosphere, the droplets reduce the amount of solar radiation reaching Earth's surface. This can cause a climatic cooling that might last for several years after a powerful eruption.

**Liquids** Magma from a volcano or fissure may remain a liquid, at least initially, and flow across the Earth's surface as lava. Magmas can vary considerably in composition, which in turn affects their physical properties.

**Viscosity** is a measure of the resistance of a fluid to flow. Liquids with low viscosity flow more easily than liquids with high viscosity. The viscosity of a liquid, such as magma, decreases as its temperature increases. For example, cold pancake syrup flows more slowly than warm pancake syrup. This means cold pancake syrup has a higher viscosity than warm pancake syrup. Other factors than affect the viscosity of magma are its gas content and chemical composition.

For example, basaltic magmas have a low viscosity and flow easily. These magmas have low viscosity because they contain less silica than other types of magmas. Basaltic magmas flow from cracks, or fissures, in Earth's crust, such as at mid-ocean ridges and continental rift zones, and from hot spot volcanoes.

The amount of gas dissolved in a magma also affects its viscosity. The more dissolved gas the magma contains, the lower its viscosity. Some magmas flow so easily that they spew out explosively when they erupt, forming a lava geyser.

## **Eruptive Styles**

Volcanoes can erupt in different ways, depending on the magma viscosity. Thick, sticky, high-silica magmas are so viscous that they tend to erupt less easily, causing the pressure within a volcano to rise. When Earth's crust cracks under such high pressure conditions, a violently explosive eruption occurs. This style of eruption is characterized by abundant pyroclasts. In contrast, the runny, low-silica, high-temperature basaltic lavas are so low in viscosity that they erupt quite easily and often produce quiet eruptions of freely flowing lava. Eruptive style is strongly linked to temperature and composition, factors that are hard to measure until after an eruption. Temperature and composition of a magma that ultimately erupts as lava can be linked to the type of plate boundary associated with it.



## **Modeling Lava Viscosity**

#### **Procedure**

## 

- 1. Mix a small batch of batter from pancake mix according to directions.
- 2. Mix a second small batch, but use 25% more milk.
- 3. Hold your finger under a small funnel and fill the funnel with the first batch of batter.
- **4.** Have a partner hold a watch with a second hand. Remove your finger and time how long it takes the funnel to empty. Record your data.
- 5. Clean the funnel and repeat step 4 using the second batch of batter.
- **6.** Gently heat a **small pan** on a hot plate.
- **7.** Pour part of the first batch of batter on the pan and observe.
- 8. Repeat step 7 using the second batch of batter.

#### **Analysis**

- 1. Which batter made the flattest pancakes? Explain
- 2. Compare and contrast the properties of the batters.
- 3. Which batter modeled low-silica lava?

**Figure 25** Many volcanoes occur on Earth along plate boundaries, over hot spots, or in rift valleys.

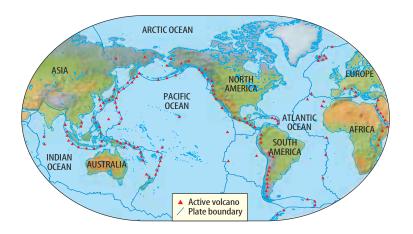


Plate Boundary Setting Look at Figure 25. Most of Earth's volcanoes are located along the plate boundaries, which rim the Pacific Ocean. They occur in subduction zones where continental and oceanic materials are being mixed and partially melted. This plate motion and the associated melting create a variety of magma types that can potentially erupt. Large earthquakes and violent volcanic eruptions often occur along these ocean-continent and ocean-ocean convergent boundaries.

Divergent plate boundaries also are volcanically active, but most of the activity is underwater, along the mid-ocean ridge, and goes unnoticed. There are places were divergence takes place on land and you could witness its associated volcanic activity. Iceland and the East African Rift Valley are examples of land areas that are part of divergent boundaries. Lava erupted in these settings is generally low-viscosity and basaltic in composition.

Hot Spots Hot spots are volcanically active sites that occur in places where large quantities of magma move to the surface in large, column-like plumes. Scientists think that plumes are positioned according to internal convection patterns within the mantle. Some plumes might originate at the core-mantle boundary. It seems that hot spots do not move much, but the plates move over them. When a hot spot occurs under an oceanic plate, this stable source of hot magma forms volcanic island chains. The Hawaiian islands are such a chain. Yellowstone National Park is an example of a hot spot under a continental plate. When a volcano moves off the hot spot it becomes inactive.

Hot spot volcanic eruptions produce lava somewhat similar to that formed along divergent boundaries. These lavas erupted at hot spots tend to contain greater abundances of alkali metals, such as potassium and sodium. Like mid-ocean ridges, hot spots, which can occur far from a plate boundary, tend to generate fluid, basaltic lavas. But their compositions can change as magmas penetrate rock material of changing composition, such as in continental crust.



## Topic: Mt. Pinatubo

Visit **gpescience.com** for Web links to information the 1991 eruption of Mt. Pinatubo in the Philippines.

**Activity** Construct a time line for this eruption. Begin with precursors, which are events that indicate volcanic activity is imminent, and end with long-term effects after the eruption.

## **Types of Volcanoes**

Volcanoes are classified according to their size, shape, and the materials that compose them. Recall that eruptive materials that form a volcano are related to the physical properties of its magma source. The temperature, composition, and gas content of magma are important controls on the type of volcanic structure that forms during an eruption. Table 3 summarizes the characteristics of main types of volcanoes.

**Cinder Cone Volcanoes** When eruption of gas-rich magma takes place, eruptive products often are spewed into the air explosively as large chunks. These large pyroclastic materials may pile up near the exit hole, or vent. When the primary eruptive products are large fragments of solid material, cinder cone volcanoes form. They tend to be small, with most cones having heights in the hundreds of meters range. When cinder cones occur on the flanks of larger volcanoes, they are called parasitic cones. An example of a volcano with parasitic cones is Mount Kilimanjaro in the African rift valley.



Reading Checker What are the characteristics of cinder cones?

**Shield Volcanoes** Because they form from high-temperature, fluid, basaltic lava, shield volcanoes erupt with abundant lava flows that can move for kilometers over Earth's surface before stopping. Shield volcanoes are broad, flat structures made up of layer upon layer of lava. Think of pancake batter. If the batter is cold or thick, it piles up and you get thick pancakes. Add more milk and make a runny batter, and it flows easily across the skillet and makes thin pancakes. Volcanism in Hawaii produces shield volcanoes.



#### **Volcano Eruptions**

Volcanic eruptions can throw tons of ash into the atmosphere where winds carry the ash around the world. The ash blocks sunlight and affects plant growth. Scientists measure fossilized tree rings to infer the affect ancient volcanoes had on Earth. Research the amount of ash produced by Mount Pinatubo and how guickly it circled the globe.

Table 3 Comparison of Melt Properties				
Composition	Silica Content	Gas Content	Viscosity	Volcano Type
Basaltic	lowest	least (1-2%)	lowest	shield, fissure eruptions (such as MOR)
Andesitic	intermediate	intermediate (3-4%)	intermediate	composite
Rhyolitic	highest	highest (4-6%)	highest	volcanic dome

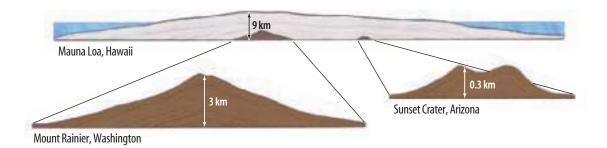


Figure 26 Shield volcanoes, like Mauna Loa, have created some of the largest mountains on Earth. Cinder cones, like Sunset Crater, are the smallest. Some of the most famous volcanoes are the composites, like Mount Rainier.

**Composite Volcanoes** When volcanoes occur along convergent boundaries, they tend to have magmas that are richer in silica content than those formed at hot spots or divergent boundaries. This is because as subduction takes place, water and sediment are forced down to regions of higher temperature. Partial melting of materials, in which the silica-rich portion of rock and sediment melts first, produces viscous magma. This produces volcanoes formed from alternating highly explosive events that form pyroclastic materials, and lava flows. These **composite volcanoes**, composed of alternating layers, are large, often thousands of meters high and tens of kilometers across the base. **Figure 26** shows all three types of volcano.

## section

## review

## **Summary**

#### **Origin of Magma**

- Magma originates as molten rock material below the surface and erupts at Earth's surface as lava.
- When the density of magma is lower than surrounding solid rock, it is forced toward Farth's surface.

#### **Eruptive Products**

• Eruptive products can be solids, liquids, or gases.

#### **Eruptive Styles**

• The style of eruption, whether quiet or explosive, is related to its plate tectonic setting.

#### **Types of Volcanoes**

- Cinder cones are small, but they erupt violently.
- Shield volcanoes are very large and mostly expel free-flowing lava quietly.
- Composite volcanoes are large and tend to erupt violently.

#### **Self Check**

- 1. Explain why most volcanoes are found at plate boundaries.
- 2. Compare and contrast the physical settings for composite volcanoes, cinder cones, and shield volcanoes.
- 3. Describe causes for variation in eruptive style for volcanoes.
- **4. Explain** how magma that originates at depth can erupt as lava at the surface.
- 5. **Describe** how island chains form over a hot spot.
- **6. Think Critically** List some possible consequences if volcanic activity on Earth were to slow down or stop.

## **Applying Math**

- 7. If a cinder cone is 540 m high and has a base diameter of 3 km, what is the volume of the volcanic cone in cubic meters? Use the formula  $V_{\text{cone}} = (r^2 h \pi)/3$ .
- 8. The dome in the caldera of the volcano has a height of 12 meters and a diameter of 50 m. What is its volume?



# A Case for Pacific Plate Motion

To measure motion you have to have a starting and an ending point. You must also know the time it took to get from start to end. Volcanic activity associated with a hot spot beneath Hawaii gives geologists exactly that.

## Real-World Problem

How can scientists show that Earth's plates are moving?

#### Goal

■ Infer a rate of movement for the Hawaiian Islands over a hot spot

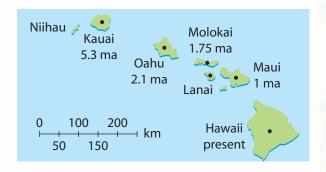
#### **Materials**

ruler calculator scale map of the Hawaiian Islands

## Procedure

- Make a data table like the one shown below.
- Measure and record the distances between the island sets in the data table. Use the map scale to convert measurements to km.
- **3.** Refer to average ages given for each island on the map. Calculate and record the age

Distance/Time Data for Hawaiian Islands				
From/To	Distance (km)	Time (years)	Rate (km/year)	
Hawaii to Maui	161			
Maui to Molokai				
Molokai to Oahu	Do not write in this book.			
Oahu to Kauai				



differences for each set of islands in the data table. Use the hot spot beneath the island of Hawaii as a starting reference point.

**4. Calculate** the rate of motion in km/year. Assume that the hot spot is stationary and that the Pacific plate is moving over it.

## Conclude and Apply

- Evaluate how meaningful your calculated rate numbers are. Determine a better rate unit and convert your km/year rates to these new units.
- **2. Infer** why the rates are not consistent using what you know about plate movement.
- **3. Describe** the overall motion of the Pacific Plate based on your data.
- **4. Observe** a map of the Pacific Ocean and infer the location of a divergent zone that could be "pushing" the Pacific plate.



Share your findings with the class and discuss alternative interpretations.



# Earthquake! Earthquake! Where's the earthquake?

#### Goals

- Examine a table of seismic wave velocities.
- Analyze data from the table.
- Determine the location of an epicenter.

#### **Possible Materials**

plain white paper graph paper compass metric ruler

### **Safety Precaution**



Understanding earthquakes begins with locating them. To determine the epicenter of an earthquake, scientists use a method called triangulation. If you know the locations of three points on a map, you can determine a fourth point. **Diagram 1** shows how triangulation works.

## 🧔 Real-World Problem

You are on vacation in City A and experience an earthquake. The radio stations are broadcasting information about the earthquake. Your home is in City B. Is your home near the epicenter?

## Procedure

- Draw a 20-cm × 15-cm rectangle on a piece of plain white paper.
   Orient the rectangle so that the 20-cm edge is vertical. This rectangle will serve as your map.
- **2.** Using a scale of 1 cm = 200 km, draw a distance scale just below the rectangle on the white paper. Place an arrow parallel to one of the 20-cm vertical edges and label it *North*.
- **3.** Within the rectangle, place City A 400 km from the north edge and 400 km from the west edge. Locate City B 800 km from the north edge and 800 km from the east edge; and City C 1,200 km from the south edge and 1,200 km from the west edge of the rectangle. Your map will look similar to **Diagram 2.**
- **4.** The earthquake happened at 08:37:00 PST. Copy and complete **Table A** on your own paper. Subtract the P-wave and S-wave arrival times to find the time differences for cities B and C.

Table A Earthquake Arrival Time Data for Cities A, B, and C					
City	P-wave Arrival	S-wave Arrival	Time Difference (min/sec)	Distance to Epicenter	Distance on Map
Α	08:40:00	08:43:00	3 min/0 sec		
В	08:41:15	08:45:00			
C	08:39:40	08:42:10			

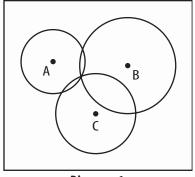
## Using Scientific Methods

- **5. Estimate** the distance from each city from Table B below.
- 6. Use the Distance on Map measurement for City A to set the compass width, and then draw the distance circle around City A on your map. Your circle may go off the map, but don't worry. The epicenter is somewhere on the arc you can draw on the map. Repeat this process for City B and City C.

Table B Seismic Wave Arrival Times				
Point	Time difference between P-waves and S-waves (min)	Distance (km) traveled by waves		
М	1.3	500		
0	2.2	1,000		
Р	3.6	2,000		
Q	4.5	3,000		
R	5.4	4,000		

## Analyze Your Data

- **1. Estimate** the time difference for P-waves and S-waves coming from 2,500 km.
- **2. Estimate** the distance for a P-wave and S-wave pair that measure a time difference of 3.3 minutes.
- **3. Determine** how much closer to the epicenter City A is than City B. City A received waves 3.0 minutes apart. City B received waves 4.2 minutes apart.



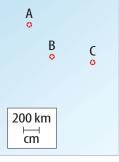


Diagram 1

Diagram 2

## Conclude and Apply-

- **1. Explain** the relationship between body wave travel time differences and the distance to an earthquake epicenter.
- **2. Evaluate** the potential danger to your home in City B. How far is your city from the epicenter?
- **3. Infer** the arrival time difference for S-waves and P-waves at or very close to the epicenter.
- **4. List** the possible sources of error in the methods you used to determine an epicenter. How can you minimize errors?



**Describe** the location of the epicenter in terms of distances from a reference point on your map. **Compare** your descriptions with others.

# TIME

## SCIENCE AND SCIENCE CAN CHANGE HISTORY THE COURSE OF HISTORY!

**THE COURSE** 

# Volcano Weather

n 1815, people worldwide noticed unusually brightly colored sunsets. Then in 1816, the weather in many parts of the world was colder than normal. In North America and Europe, 1816 was known as "the year without a summer." Parts of New England had damaging frosts in July and August. The fantastic sunsets and the cold summer resulted from the eruption of Tambora, a volcano in Indonesia.

#### **Giant Weather Makers**

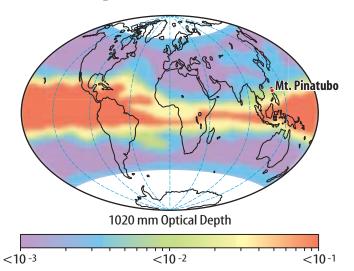
Communication was slow in the early nineteenth century, so scientists immediately did not connect Tambora's eruption to weather changes. Today, many researchers study the effects of volcanic eruptions on weather. When Mount Pinatubo in the Philippines erupted in June 1991, weather stations around the world recorded its effects.

Mt. Pinatubo's eruption was smaller than Tambora's, but was the second largest eruption in over 100 years. It blew ash and gases into the stratosphere. Some of the gases formed small droplets, which remained suspended in the stratosphere for several years and were carried by winds around the world. Because the suspended droplets reflected sunlight, average temperatures temporarily dropped by about 0.5°C in many places. Other weather-related affects included the increased strength of hurricanes in the

Atlantic and Pacific Oceans and as well as flooding rains in the U.S. Midwest.

#### **Looking Back at Volcanoes**

The effect of volcanoes on climate is so important that some scientists even study volcanic eruptions from thousands of years ago. They compare the dates of these ancient eruptions with records of unusual weather. It has been found that crop failures and disease epidemics often occurred soon after large eruptions. Because changes in weather can affect the growth of trees, the growth rings of ancient trees also are evidence that support the data from written records. These ancient records help scientist predict the weather impacts of future volcanic eruptions.



**Experiment** Lay two sheets of black construction paper on a sunny windowsill and place a thermometer on each sheet. Tape a large piece of gauze or cheesecloth to the window so that it shades one of the sheets. Record the change in temperature for one half hour.



## **Reviewing Main Ideas**

## **Section 1 Evolution of Earth's Crust**

- **1.** Earth's crust and uppermost mantle, together called the lithosphere, consist of about seven large and numerous smaller plates.
- **2.** Plate motion over the asthenosphere is influenced by forces that include ridge push, frictional drag, and slab pull.
- **3.** Mantle convection drives the system of plates. Thermal energy sources for convection include heat left over from Earth's formation, and decay of radioactive isotopes.
- **4.** Plates meet along divergent, convergent, and transform boundaries.



## **Section 2 Earthquakes**

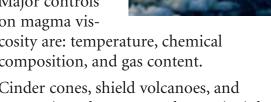
- **1.** Earthquakes are vibrations in Earth caused by the sudden release of energy.
- **2.** During an earthquake caused by movement along a fault, strain energy is released in the form of seismic waves.
- **3.** Most earthquake activity is confined to regions near plate boundaries.
- **4.** Short-term prediction of earthquakes is not yet possible, but earthquakes can be rated by their intensities and magnitudes.

#### Section 3 **Earth's Interior**

- 1. The interior of Earth consists of four main layers: crust, mantle, inner and outer core.
- **2.** The crust and mantle are largely composed of solid silicates. The asthenosphere is a layer of mantle in a semi-solid state.
- **3.** The two innermost layers, the inner and outer core, are mainly composed of iron, nickel, oxygen and sulfur. The outer core is in a liquid state, and the inner core is solid.
- **4.** The crust is the thinnest layer, while the mantle is the thickest.

## **Section 4 Volcanoes**

- 1. Most volcanic activity on Earth occurs in the vicinity of plate boundaries or above mantle plumes.
- 2. The viscosity of the magma feeding volcanoes controls the volcanoes' eruptive characteristics.
- 3. Major controls on magma viscosity are: temperature, chemical composition, and gas content.
- 4. Cinder cones, shield volcanoes, and composite volcanoes are three principle volcanic landforms.



FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review Earth's internal process.

## **Using Vocabulary**

asthenosphere p. 372	
cinder cone volcano	
p. 377	
composite volcano p. 37	7
convergent boundary	
p. 359	
discontinuity p. 371	
divergent boundary	
p. 358	
elastic rebound p. 364	
epicenter p. 364	

fault p.364
focus p.364
mid-ocean ridge p.356
rift valley p.356
shadow zone p.371
shield volcano p.377
subduction p.359
transform boundary
p.360
viscosity p.375

Complete each sentence with the correct vocabulary word or words.

- **1.** The \_\_\_\_\_\_ is the point of origin of an earthquake.
- **2.** A zone of cracking in Earth's crust along which movement takes place is a \_\_\_\_\_
- **3.** A long, linear feature within a divergent plate boundary is a(n) \_\_\_\_\_\_.
- **4.** A feature consisting of a relatively small pile of pyroclastic materials is a(n) \_\_\_\_\_\_.
- **5.** A boundary marking an abrupt change in density is a(n) \_\_\_\_\_.

## **Checking Concepts**

Choose the word or phrase that best answers the question.

- **6.** What process causes an object to permanently change its shape?
  - A) plastic deformation
  - **B)** elastic rebound
  - **c)** elastic deformation
  - **D)** brittle deformation
- 7. Which best identifies a shield volcano?
  - A) sticky, silica-rich magmas
  - **B)** great height compared to width
  - **c)** forms above hot spots
  - **D)** found mostly on continents

- **8.** What characteristic was first used to identify Earth's layers?
  - A) temperature
- **c)** density
- **B)** composition
- **D)** thickness
- **9.** Which pair of plate tectonic boundaries is best characterized by mostly shallow earthquakes?
  - **A)** divergent and transform
  - **B)** divergent and continent-ocean convergent
  - **c)** continent-continent and continent-ocean convergent
  - **D)** transform and ocean-ocean convergent zones
- **10.** Which feature is common to and only found in diverging regions?
  - **A)** trenches
- **c)** volcanic arcs
- **B)** rift valleys
- **D)** island arcs
- **11.** Which is **NOT** evidence used by Wegener to support the continental drift hypothesis?
  - **A)** matching magnetic patterns symmetrical to the Mid-Ocean Ridge
  - **B)** matching of continental margins
  - **c)** correlation of fossils among the continents
  - **D)** mountain-range matching among the continents

Use the illustration below to answer question 12.

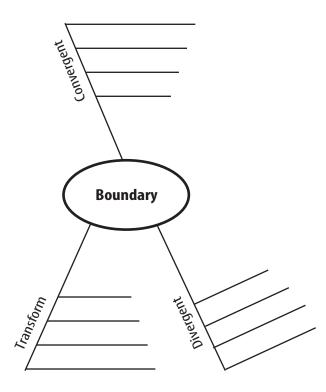


- **12.** Which volcano type has small height, small diameter and consists mostly of pyroclasts?
  - A) Hawaiian volcano
  - B) cinder cone volcano
  - **C)** composite volcano
  - **D)** shield volcano

- **13.** Which earthquake waves have the greatest speed as they move in Earth?
  - **A)** secondary waves
  - **B)** surface waves
  - c) primary waves
  - **D)** body waves

## **Interpreting Graphics**

**14.** Copy and complete the concept map below summarizing characteristics of divergent, convergent and transform plate boundaries.



**15.** Copy and complete the table summarizing three types of volcanoes.

Magma Properties and Volcano Types				
General Composition	Relative silica (SiO <sub>2</sub> ) Content	Relative Viscosity	Volcano Type	
		lowest		
Andesitic	intermediate			
	highest		Lava Dome	

## **Thinking Critically**

- **16.** Explain why the island of Kauai, often referred to as the "Garden Isle," has thicker soils and is better able to sustain agriculture than other Hawaiian Islands.
- **17. Infer** why there are more volcanoes in the Andes mountains than in the Himalaya.
- **18. Explain** how the processes associated with plate tectonics maintain Earth's recycling of materials.

## **Applying Math**

- **19.** Calculating Lava Thickness Suppose that hot spot volcanism produces an average of 76,000 m<sup>3</sup> of lava per day and does so for 340 days. This lava flows across a region that has an area of 10 km<sup>2</sup>. How thick will the resulting lava flow be?
- **20.** Located on the island of Hawaii, Mauna Loa is the largest volcano on Earth and rises 17 km above its base. Using the thickness you found in question 19 as the annual thickness, how many years did it take for Mauna Loa to build from the sea bed?
- **21.** Mauna Loa rises 4 km above sea level. How many years did it take to grow from sea level to its present height?
- **22.** An active volcano called Loihi lies just off the coast of the island of Hawaii. It is called a seamount because it still lies below the surface. If it grows at the same rate you used in question 21 and lies 1250 m below the surface, how long will it take for Loihi to break the ocean surface?

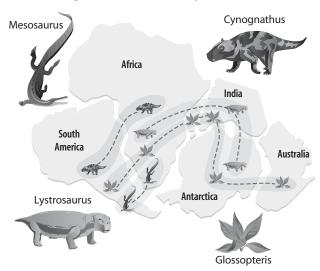
## Standardized Test Practice chapter

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

## **Multiple Choice**

- 1. Who first proposed the hypothesis of continental drift?
  - A. Matthews
  - **B.** Vine
  - **C.** Wegener
  - D. Wilson

#### Use the image below to answer question 2.



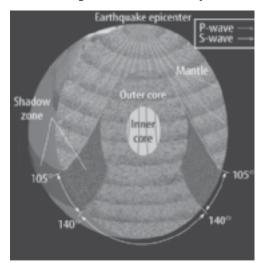
- 2. Which is the fern, pictured above, that provided support for Pangaea?
  - A. Antarctica
  - **B.** Glossopteris
  - **C.** Mesosaurus
  - **D.** Lystrosaurus

#### Test-Taking Tip

For each question, double-check that you are filling in the correct answer bubble for the question number you are completing.

- **3.** What did oceanographers show, using sonar, which helped revive continental drift?
  - **A.** edges of the continental shelves matched
  - **B.** edges of the continents matched
  - **C.** fossils match similar fossils
  - **D.** rocks match similar rocks
- **4.** Which forms when a less-dense plate converges on a denser plate?
  - **A.** mid-ocean ridge
  - **B.** rift valley
  - **c.** subduction zone
  - **D.** transform boundary

#### Use the image below to answer question 5.



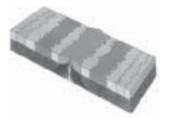
- **5.** The shadow zone, illustrated above, is caused by which layer of Earth?
  - **A.** crust
  - **B.** mantle
  - **C.** outer core
  - **D.** inner core

#### **Gridded Response**

- **6.** If a divergent boundary separates at a rate of 2.5 cm/year, how much farther apart would the two plates be after 230 years?
- **7.** Compared to the two plates in question 7, how much farther apart would two plates be after 230 years if the divergent boundary between them separated at 15 cm/year?

#### Short Response

Use the illustration below to answer question 8.

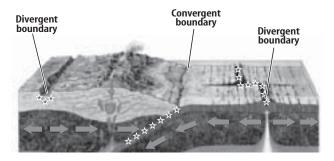


- **8.** The illustration shows reverse polarity bands on the seafloor. How does magnetic polarity of rocks support seafloor spreading?
- **9.** What are the three ways in which tectonic plates can move at their boundaries?
- **10.** What is different about what happens to plate edges at the different types of convergent boundaries?
- **11.** How did Dr. Harry Hess obtain detailed maps of the ocean floor?
- **12.** What causes a rift valley to form at divergent boundaries?

- **13.** What is true about the age of sediments at different locations on the ocean floor that supports seafloor spreading?
- **14.** What is the driving force for all mechanisms of tectonic plate movement?
- **15.** What is the difference between a fracture in Earth's crust and a fault?
- **16.** What causes the energy of an earthquake?
- **17.** How are the focus and epicenter of an earthquake related?

### Extended Response

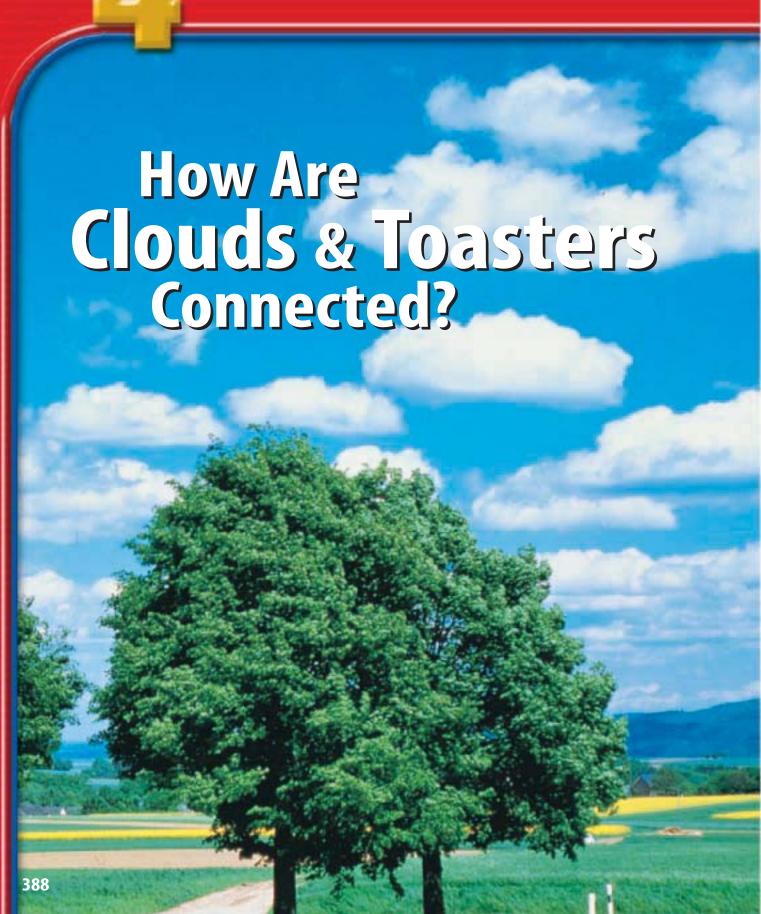
Use the image below to answer question 18.



- **18. Part A** What is true about the depth of earthquakes and the location of tectonic plate boundaries?
  - Part B Why do deep earthquakes occur only at ocean-ocean convergent boundaries and ocean-continental convergent boundaries?



## Forms of Energy







## chapter



## BIG (Idea

The flow of electric charges in a circuit is a source of electrical energy.

## 13.1 Electric Charge

MAIN (Idea Like electric charges attract each other and unlike charges repel.

#### 13.2 Electric Current

MAIN (Idea A voltage difference causes electrons to flow in a circuit.

### 13.3 Electrical Energy

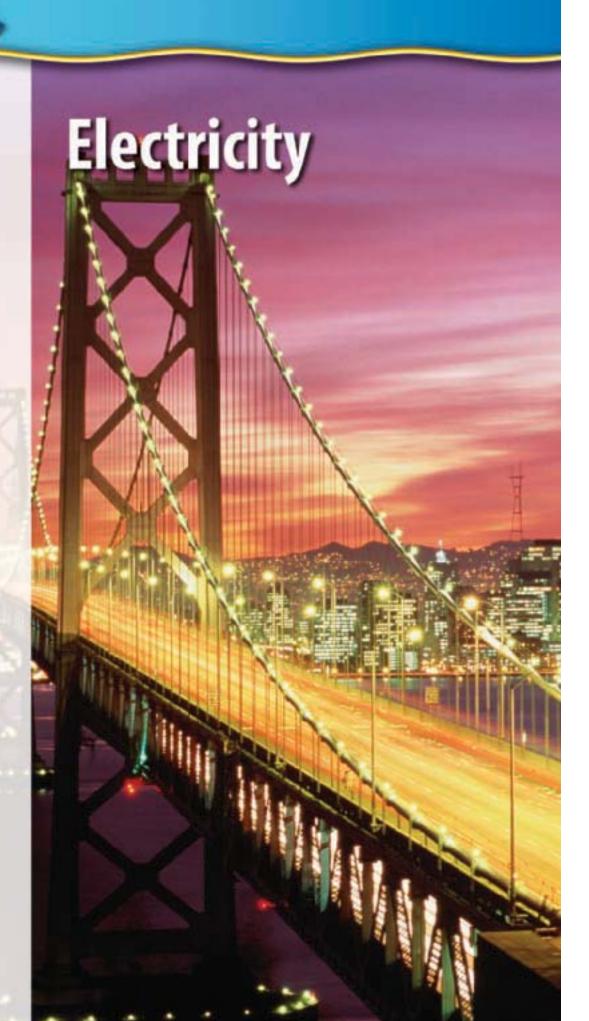
MAIN (Idea Electrical energy can be converted into other forms of energy in a circuit.

## Shine on Brightly

Electricity lights up this city so that people can continue to work or have fun when it gets dark. Electric lights and other electric devices operate by converting electrical energy into other forms of energy.

#### **Science Journal**

For five electric devices, list the form of energy electrical energy is converted into by each device.



## **Start-Up Activities**



## **Electric Circuits**

No lights! No CD players! No computers, video games or TVs! Without electricity, many of the things that make your life enjoyable wouldn't exist. For these devices to operate, electric current must flow in the electric circuits that are part of the device. Under what conditions does electric current flow in an electric circuit?

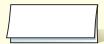


- 1. Complete the safety form.
- **2.** Obtain a battery, a flashlight bulb, and some wire.
- **3.** Connect the materials so that the lightbulb lights.
- 4. Draw diagrams of all the ways that you were able to light the bulb.
- 5. Record a few of the ways that didn't work.
- **6.** Can you light the bulb using only one wire and the battery?
- 7. Think Critically Write a paragraph describing the requirements to light the bulb. Write out a procedure for lighting the bulb and have a classmate follow your procedure.



**Electricity** Make the following Foldable to help you organize information about electricity.

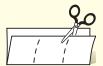
Fold a sheet of paper vertically from top to bottom. Make the top edge about 2 cm shorter than the bottom edge.



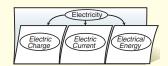
STEP 2 Turn lengthwise and fold into thirds.



STEP 3 Unfold and cut only the top layer along both folds to make three tabs.



STEP 4 Label the Foldable as shown.



**Organize Information** As you read the chapter, organize the information you find about electric charge, electric current, and electrical energy under the appropriate tab.



Preview this chapter's content and activities at gpescience.com

# **Electric Charge**

## **Reading Guide**

## What You'll Learn

- Describe how electric charges exert forces on each other.
- **Compare** the strengths of electric and gravitational forces.
- Distinguish between conductors and insulators.
- **Explain** how objects become electrically charged.

## Why It's Important

The electrical energy that all electrical devices use comes from the forces that electric charges exert on each other.

## Review Vocabulary

atom: the smallest particle of an element

### New Vocabulary

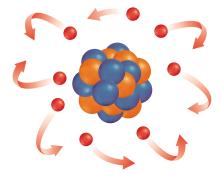
- static electricity
- law of conservation of charge
- conductor
- insulator
- charging by contact
- charging by induction

## **Positive and Negative Charge**

Why does walking across a carpeted floor and then touching something sometimes result in a shock? The answer has to do with electric charge. Atoms contain particles called protons, neutrons, and electrons, as shown in **Figure 1.** Protons and electrons have electric charge, and neutrons have no electric charge.

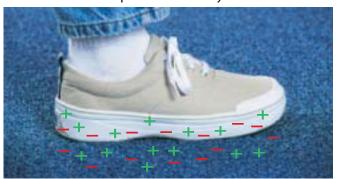
There are two types of electric charge. Protons have positive electric charge and electrons have negative electric charge. The amount of positive charge on a proton equals the amount of negative charge on an electron. If an atom contains equal numbers of protons and electrons, the positive and negative charges cancel out and the atom has no net electric charge. Objects with no net charge are said to be electrically neutral.

**Transferring Charge** Electrons are bound more tightly to some atoms and molecules. For example, compared to the electrons in atoms in the carpet, electrons are bound more tightly to the atoms in the soles of your shoes. **Figure 2** shows that when you walk on carpet, electrons are transferred from the carpet to the soles of your shoes. The soles of your shoes have an excess of electrons and become negatively charged. The carpet has lost electrons and has an excess of positive charge. The carpet has become positively charged. The accumulation of excess electric charge on an object is called static electricity.

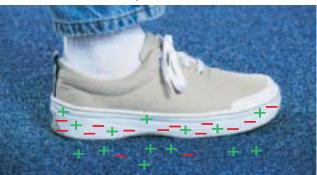


**Figure 1** The center of an atom contains protons (orange) and neutrons (blue). Electrons (red) swarm around the atom's center.

Before the shoe scuffs against the carpet, both the sole of the shoe and the carpet are electrically neutral.



As the shoe scuffs against the carpet, electrons are transferred from the carpet to the sole of the shoe.



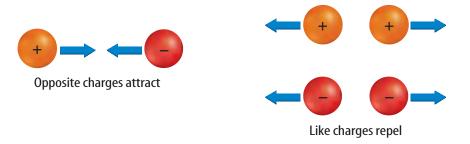
**Conservation of Charge** When an object becomes charged, charge is neither created nor destroyed. Usually it is electrons that have moved from one object to another. According to the law of conservation of charge, charge can be transferred from object to object, but it cannot be created or destroyed. Whenever an object becomes charged, electric charges have moved from one place to another.

Reading Check How does an object become charged?

**Charges Exert Forces** Have you noticed how clothes sometimes cling together when removed from the dryer? These clothes cling together because of the forces electric charges exert on each other. Figure 3 shows that unlike charges attract each other and like charges repel each other. The force between electric charges also depends on the distance between charges. The force decreases as the charges get farther apart.

Just as for two electric charges, the force between any two objects that are electrically charged decreases as the objects get farther apart. This force also depends on the amount of charge on each object. As the amount of charge on either object increases, the electrical force also increases.

As clothes tumble in a dryer, the atoms in some clothes gain electrons and become negatively charged. Meanwhile the atoms in other clothes lose electrons and become positively charged. Clothes that are oppositely charged attract each other and stick together.

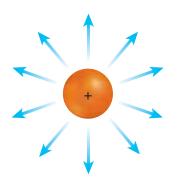


tightly than atoms in the carpet hold their electrons. **Explain** how the sole gained charge even though charge can't be created or destroyed.

**Figure 2** Atoms in the shoe's

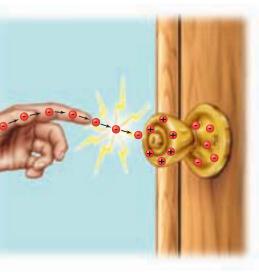
sole hold their electrons more

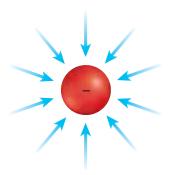
**Figure 3** Positive and negative charges exert forces on each other.



**Figure 4** Surrounding every electric charge is an electric field that exerts forces on other electric charges. The arrows point in the direction a positive charge would move.

Figure 5 As you walk across a carpeted floor, excess electrons can accumulate on your body. When you reach for a metal doorknob, electrons flow from your hand to the doorknob and you see a spark.





**Electric Fields** You might have seen bits of paper fly up and stick to a charged balloon. The bits of paper do not need to touch the charged balloon for an electric force to act on them. If the balloon and the paper are not touching, what causes the paper to move?

An electric field surrounds every electric charge, as shown in **Figure 4,** and exerts the force that causes other electric charges to be attracted or repelled. Any charge that is placed in an electric field will be pushed or pulled by the field. Electric fields are represented by arrows that show how the electric field would make a positive charge move.

The Strength of Electric Forces The force of gravity between you and Earth seems to be strong. Yet, compared with electric forces, the force of gravity is much weaker. For example, the attractive electric force between a proton and an electron in a hydrogen atom is about a thousand trillion trillion times larger, or 10<sup>39</sup> times larger, than the attractive gravitational force between the two particles.

In fact, all atoms are held together by electric forces between protons and electrons that are tremendously larger than the gravitational forces between the same particles. The chemical bonds that form between atoms in molecules also are due to the electric forces between the atoms. These electric forces are much larger than the gravitational forces between the atoms.



Compare the strength of electric and gravitational forces between protons and electrons.

#### Some Observable Forces are due to Electric Forces

Many of the forces that act on objects are due to the electric forces between atoms and molecules. All atoms contain electrically charged electrons and protons. When atoms or molecules get close enough, they can exert electric forces on each other that can be attractive or repulsive. For example, when you push on a door, the atoms on the surface of your hand get close to the atoms on the surface of the door. These atoms are close enough that they exert electric forces on each other. The electric forces the atoms in your hand exert on the atoms in the door cause the door to move. The frictional force between two surfaces in contact is due to the attractive electric forces between the atoms on the two surfaces. These forces cause the surfaces to stick together.

## **Conductors and Insulators**

If you reach for a metal doorknob after walking across a carpet, you might see a spark. The spark is caused by electrons moving from your hand to the doorknob, as shown in **Figure 5.** Recall that electrons were transferred from the carpet to your shoes. How did these electrons move from your shoes to your hand?

**Conductors** A material in which electrons are able to move easily is a **conductor**. Electrons on your shoes repel each other and some are pushed onto your skin. Because your skin is a better conductor than your shoes, the electrons spread over your skin, including your hand.

The best electrical conductors are metals. The atoms in metals have electrons that are able to move easily through the material. Electric wires usually are made of copper because copper metal is one of the best conductors.

**Insulators** A material in which electrons are not able to move easily is an **insulator**. Electrons are held tightly to atoms in insulators. Most plastics are insulators. The plastic coating around electric wires, such as the one shown in **Figure 6**, prevents a dangerous electric shock when you touch the wire. Other good insulators are wood, rubber, and glass.

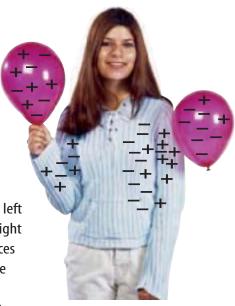
## **Charging Objects**

You might have noticed socks clinging to each other after they have been tumbling in a clothes dryer. Rubbing two materials together can result in a transfer of electrons. Then one material is left with a positive charge and the other with an equal amount of negative charge. The process of transferring charge by touching or rubbing is called charging by contact.

**Figure 6** The plastic coating around wires is an insulator. A damaged electrical cord is hazardous when the conducting wire is exposed.

**Explain** how the coating on a wire prevents an electric shock.





**Figure 7** The balloon on the left is neutral. The balloon on the right is negatively charged. It produces a positively charged area on the sleeve by repelling electrons. **Determine** the direction of the *electric force acting on the balloon.* 

## **Charging at a Distance**

Because electrical forces act at a distance, charged objects brought near a neutral object will cause electrons to rearrange their positions on the neutral object. Suppose you charge a balloon by rubbing it with a cloth. If you bring the negatively charged balloon near your sleeve, the extra electrons on the balloon repel the electrons in the sleeve. The electrons near the sleeve's surface move away from the balloon, leaving a positively charged area on the surface of the sleeve, as

shown in **Figure 7.** As a result, the negatively charged balloon attracts the positively charged area of the sleeve. The rearrangement of electrons on a neutral object caused by a nearby charged object is called **charging by induction**. The sweater was charged by induction. The balloon will now cling to the sweater, being held there by an electrical force.

**Lightning** Have you ever seen lightning strike Earth? Lightning is a large static discharge. A static discharge is a transfer of charge between two objects because of a buildup of static electricity. A thundercloud is a mighty generator of static electricity. As air masses move and swirl in the cloud, areas of positive and negative charge build up. Eventually, enough charge builds up to cause a static discharge between the cloud and the ground. As the electric charges move through air, they collide with atoms and molecules. These collisions cause the atoms and molecules in air to emit light. You see this light as a spark, as shown in **Figure 8.** 

**Thunder** Not only does lightning produce a brilliant flash of light, it also generates powerful sound waves. The electrical energy in a lightning bolt rips electrons off atoms in the air and produces great amounts of thermal energy. The surrounding air temperature can rise to about 25,000°C—several times hotter than the Sun's surface. The hot air in the lightning bolt's path expands rapidly, producing sound waves that you hear as thunder.

The sudden discharge of so much energy can be dangerous. It is estimated that Earth is struck by lightning about 100 times every second. Lightning strikes can cause power outages, injury, loss of life, and fires.



**Topic: Lightning** 

Visit **gpescience.com** for Web links to information about lightning strikes.

**Activity** Make a table listing tips on how people can protect themselves from lightning.

## **NATIONAL** GEOGRAPHIC VISUALIZING LIGHTNING

## Figure 8

torm clouds can form when humid, Sun-warmed air rises to meet a colder air layer. As these air masses churn together, the stage is set for the explosive electrical display we call lightning. Lightning strikes when negative charges at the bottom of a storm cloud are attracted to positive charges on the ground.

(A) Convection currents in the storm cloud cause charge separation. The top of the cloud becomes positively charged, the bottom negatively charged.

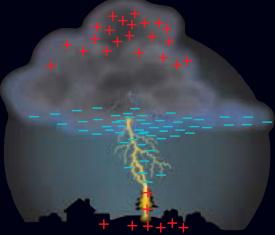




B Negative charges on the bottom of the cloud induce a positive charge on the ground below the cloud by repelling negative charges in the ground.



When the bottom of the cloud has accumulated enough negative charges, the attraction of the positive charges below causes electrons in the bottom of the cloud to move toward the ground.



D When the electrons get close to the ground, they attract positive charges that surge upward, completing the connection between cloud and ground. This is the spark you see as a lightning flash.



**INTRACLOUD LIGHTNING never strikes Earth and** can occur ten times more often in a storm than cloud-to-ground lightning.

**Figure 9** A lightning rod directs the charge from a lightning bolt safely to the ground.



## **Investigating Charged Objects**

#### **Procedure**

- 1. Complete the safety form.
- 2. Fold over about 1 cm on the end of a roll of transparent tape to make a handle. Tear off a strip of tape about 10 cm long.
- 3. Stick the strip to a clean, dry, smooth surface, such as a countertop. Make an identical strip and stick it directly on top of the first.
- **4.** Pull both pieces off the counter together and pull them apart. Bring the nonsticky sides of both tapes together. What happens?
- 5. Stick the two strips of tape side by side on the smooth surface. Pull them off and bring the nonsticky sides near each other again.

#### **Analysis**

- 1. What happened when you brought the pieces close together the first time? How were they charged? What might have caused this?
- 2. What happened when you brought the pieces together the second time? How were they charged? What did you do that might have changed the behavior?



**Grounding** The sensitive electronics in computer can be harmed by large static discharges. A discharge can occur any time that charge builds up in one area. Providing a path for charge to reach Earth prevents any charge from building up. Earth is a large, neutral object that is also a conductor of charge. Any object connected to Earth by a good conductor will transfer any excess electric charge to Earth. Connecting an object to Earth with a

conductor is called grounding. For example, to prevent damage by lightning, buildings often have a metal lightning rod that provides a conducting path from the highest point on the building to the ground, as shown in Figure 9.

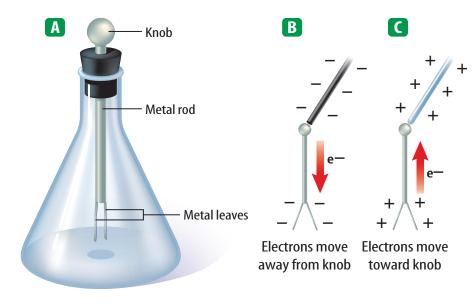
Plumbing fixtures, such as metal faucets, sinks, and pipes, often provide a convenient ground connection. Look around. Do you see anything that might act as a path to the ground?

## **Detecting Electric Charge**

The presence of electric charges can be detected by an electroscope. One kind of electroscope is made of two thin, metal leaves attached to a metal rod with a knob at the top. The leaves are allowed to hang freely from the metal rod. When the device is not charged, the leaves hang straight down, as shown in Figure 10A.

Suppose a negatively charged rod touches the knob. Because the metal is a good conductor, electrons travel down the rod into the leaves. Both leaves become negatively charged as they gain electrons, as shown in Figure 10B. Because the leaves have similar charges, they repel each other.

If a glass rod is rubbed with silk, electrons move away from the atoms in the glass rod and build up on the silk. The glass rod becomes positively charged.



**Figure 10** Notice the position of the leaves on the electroscope when they are A uncharged, **B** negatively charged, and c positively charged. **Infer** How can you tell whether an electroscope is positively or

negatively charged?

When the positively charged glass rod is brought into contact with the metal knob of an uncharged electroscope, electrons flow out of the metal leaves and onto the rod. The leaves repel each other because each leaf becomes positively charged as it loses electrons, as shown in **Figure 10C.** 

## section

## review

## **Summary**

#### **Positive and Negative Charge**

- There are two types of electric charge: positive charge and negative charge.
- Electric charges can be transferred between objects but cannot be created or destroyed.
- Like charges repel and unlike charges attract.
- An electric charge is surrounded by an electric field that exerts forces on other charges.

#### **Electrical Conductors and Insulators**

- A conductor contains electrons that can move easily. The best conductors are metals.
- The electrons in an electrical insulator do not move easily. Rubber, glass, and most plastics are examples of insulators.

#### **Charging Objects**

- Electric charge can be transferred between objects by bringing them into contact.
- Charging by induction occurs when the electric field around a charged object rearranges electrons in a nearby neutral object.

#### **Self Check**

- 1. **Define** static electricity.
- 2. Describe how lightning is produced.
- 3. Explain why electrically neutral objects can become electrically charged even though charge cannot be created or destroyed.
- **4. Predict** what would happen if you touched the knob of a positively charged electroscope with another positively charged object.
- 5. Think Critically Humid air is a better electrical conductor than dry air. Explain why you're more likely to receive a shock after walking across a carpet when the air is dry than when the air is humid.

### **Applying Math**

- 6. Determine Lightning Strikes Earth is struck by lightning 100 times each second. How many times is Earth struck by lightning in one day?
- 7. Calculate Electric Force A balloon with a mass of 0.020 kg is charged by rubbing and then is stuck to the ceiling. If the acceleration of gravity is 9.8 m/s<sup>2</sup>, what is the electrical force on the balloon?

## **Electric Current**

## **Reading Guide**

## What You'll Learn

- Describe how voltage difference causes current to flow.
- **Explain** how batteries produce a voltage difference in a circuit.
- List the factors that affect an object's electrical resistance.
- Define Ohm's law.

## Why It's Important

You control electric current every time you change the volume on a TV, stereo, or CD player.

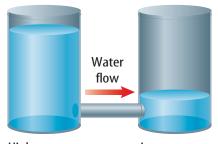
## Review Vocabulary

pressure: amount of force exerted per unit area

### **New Vocabulary**

- electric current
- voltage difference
- circuit
- resistance
- Ohm's law

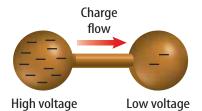
**Figure 11** Electric forces in a material cause electric current to flow, just as forces in the water cause water to flow.



High pressure

Low pressure

The force that causes water to flow is related to a pressure difference.



The force that causes a current to flow is related to a voltage difference.

## **Current and Voltage Difference**

When a spark jumps between your hand and a metal doorknob, electric charges move quickly from one place to another. The net movement of electric charges in a single direction is an electric current. In a metal wire, or any material, electrons are in constant motion in all directions. As a result, there is no net movement of electrons in one direction. However, when an electric current flows, electrons continue their random movement, but they also drift in the direction that the electron current flows.

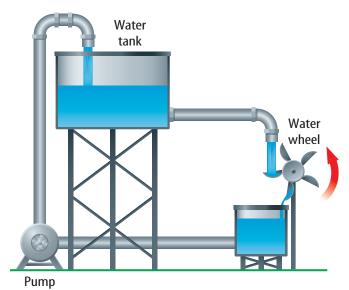
Electric current is measured in amperes. One ampere is equal to 6,250 million billion electrons flowing past a point every second.

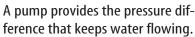
Reading Check What is electric current?

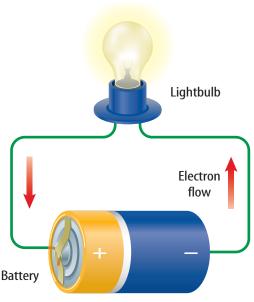
**Voltage Difference** The movement of an electron in an electric current is similar to a ball bouncing down a flight of stairs. Even though the ball changes direction when it strikes a stair, the net motion of the ball is downward. The downward motion of the ball is caused by the force of gravity. When a current flows, the net movement of electric charges is caused by an electric force acting on the charges.

In some ways, the electric force that causes charges to flow is similar to the force acting on the water in a pipe. Water flows from higher pressure to lower pressure, as shown in **Figure 11.** In a similar way, electric charge flows when there is a voltage difference. A voltage difference is related to the force that causes electric charges to flow. Voltage difference is measured in volts.

**Figure 12** Water or electric current will flow continually only through a closed loop. If any part of the loop is broken or disconnected, the flow stops.







A battery provides the voltage difference that keeps electric current flowing.

**Electric Circuits** One way to have flowing water perform work is shown in **Figure 12.** Water flows out of the tank and falls on a paddle wheel, causing it to rotate. A pump then provides a pressure difference that lifts the water back up into the tank. The constant flow of water would stop if the pump stopped working. The flow of water also would stop if one of the pipes broke. Then water no longer could flow in a closed loop, and the paddle wheel would stop rotating.

**Figure 12** also shows an electric current doing work by lighting a lightbulb. Just as the water current stops flowing if there is no longer a closed loop to flow through, the electric current stops if there is no longer a closed path to follow. A closed path that electric current follows is a **circuit**. If the circuit in **Figure 12** is broken by removing the battery, the lightbulb, or one of the wires, current will not flow.

## **Batteries**

To keep water flowing continually in the water circuit in **Figure 12,** a pump is used to provide a pressure difference. In a similar way, to keep an electric current continually flowing in the electric circuit in **Figure 12,** a voltage difference needs to be maintained in the circuit. A battery can provide the voltage difference that is needed to keep current flowing in a circuit. Current flows as long as there is a closed path that connects one battery terminal to the other battery terminal.



## **Investigating Battery Addition**



- **1.** Complete the safety form.
- 2. Connect two bulbs and one D-cell battery in a loop to make a circuit.
- 3. Add another battery by connecting the negative terminal of one battery to the positive terminal of the other.
- **4.** Compare the brightness of the bulbs in the two circuits.

#### **Analysis**

- **1.** Add the voltage difference for each battery to find the voltage difference in the circuit in step 2.
- 2. If the brightness of a bulb increases as the current increases, how are the current and the voltage difference in a circuit related?

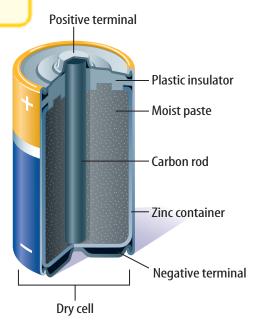
Dry-Cell Batteries You probably are most familiar with drycell batteries. A cell consists of two electrodes surrounded by a material called an electrolyte. The electrolyte enables charges to move from one electrode to the other. Look at the dry cell shown in **Figure 13.** One electrode is the carbon rod, and the other is the zinc container. The electrolyte is a moist paste containing several chemicals. The cell is called a dry cell because the electrolyte is a moist paste, not a liquid solution.

When the two terminals of a dry-cell battery are connected in a circuit, such as in a flashlight, a reaction involving zinc and several chemicals in the paste occurs. Electrons are transferred between some of the compounds in this chemical reaction. As a result, the carbon rod becomes positive, forming the positive (+) terminal. Electrons accumulate on the zinc, making it the negative (-) terminal.

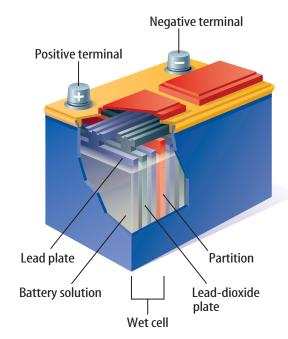
The voltage difference between these two terminals causes current to flow through a closed circuit. You make a battery when you connect two or more cells together to produce a higher voltage difference.

**Wet-Cell Batteries** Another commonly used type of battery is the wet-cell battery. A wet cell, like the one shown in **Figure 13**, contains two connected plates made of different metals or metallic compounds in a conducting solution. A wet-cell battery contains several wet cells connected together.

Figure 13 Chemical reactions in batteries produce a voltage difference between the positive and negative terminals. **Identify** when these chemical reactions occur.



In this dry cell, chemical reactions in the moist paste transfer electrons to the zinc container.



In this wet cell, chemical reactions transfer electrons from the lead plates to the lead-dioxide plates.

**Lead-Acid Batteries** Most car batteries are lead-acid batteries, like the wet-cell battery shown in **Figure 13.** A lead-acid battery contains a series of six wet cells made up of lead and lead dioxide plates in a sulfuric acid solution. The chemical reaction in each cell provides a voltage difference of about 2 V, giving a total voltage difference of 12 V. As a car is driven, the alternator recharges the battery by sending current through the battery in the opposite direction to reverse the chemical reaction.

A voltage difference is provided at electrical outlets, such as a wall socket. This voltage difference usually is higher than the voltage difference provided by batteries. Most types of household devices are designed to use the voltage difference supplied by a wall socket. In the United States, the voltage difference across the two holes in a wall socket is usually 120 V. Some wall sockets supply 240 V, which is required by appliances such as electric ranges and electric clothes dryers.

## **Resistance**

Flashlights use dry-cell batteries to provide the electric current that lights a lightbulb. What makes a lightbulb glow? Look at the lightbulb in **Figure 14.** Part of the circuit through the bulb is a thin wire called a filament. As the electrons flow through the filament, they bump into the metal atoms that make up the filament. In these collisions, some of the electrical energy of the electrons is converted into thermal energy. Eventually, the metal filament becomes hot enough to glow, producing radiant energy that can light up a dark room.

**Resisting the Flow of Current** Electric current loses energy as it moves through the filament because the filament resists the flow of electrons. **Resistance** is the tendency of a material to oppose the flow of electrons, changing electrical energy into thermal energy and light. With the exception of some substances that become superconductors at low temperatures, all materials have some electrical resistance. Electrical conductors have much less resistance than insulators. Resistance is measured in ohms  $(\Omega)$ .

Copper is an excellent conductor and has low resistance to the flow of electrons. Copper is used in household wiring because only a small amount of electrical energy is converted to thermal energy as current flows in copper wires.



**Figure 14** As electrons move through the filament in a lightbulb, they bump into metal atoms. Due to the collisions, the metal heats up and starts to glow.

**Describe** the energy conversions that occur in a lightbulb filament.

**Temperature, Length, and Thickness** The electric resistance of most materials usually increases as the temperature of the material increases. The resistance of an object such as a wire also depends on the length and diameter of the wire. The resistance of a wire, or any conductor, increases as the wire becomes longer. The resistance also increases as the wire becomes thinner.

In a 60-W lightbulb, the filament is a piece of tungsten wire made into a short coil a few centimeters long. The uncoiled wire is about 2 m long and only about 0.25 mm thick. Even though tungsten metal is a good conductor, by making the wire thin and long, the resistance of the filament is made large enough to cause the bulb to glow.



How does changing the length and thickness of a wire affect its resistance?

## The Current in a Simple Circuit

A simple electric circuit contains a source of voltage difference, such as a battery, a device that has resistance, such as a lightbulb, and conductors that connect the device to the battery terminals. When the wires are connected to the battery terminals, current flows in the closed path. An example of a simple circuit is shown in **Figure 15.** 

The voltage difference, current, and resistance in a circuit are related. If the voltage difference doesn't change, decreasing the resistance increases the current in the circuit, as shown in **Figure 15.** Also, if the resistance doesn't change, increasing the voltage difference increases the current.

**Figure 15** The amount of current flowing through a circuit is related to the amount of resistance in the circuit.



When the clips on the graphite rod are farther apart, the resistance of the rod in the circuit is larger. As a result, less current flows in the circuit and the lightbulb is dim.

When the clips on the graphite rod are closer together, the resistance of the rod in the circuit is less. As a result, more current flows in the circuit and the lightbulb is brighter.

**Ohm's Law** The relationship among voltage difference, current, and resistance in a circuit is known as Ohm's law. According to **Ohm's law**, the current in a circuit equals the voltage difference divided by the resistance. Ohm's law can be written as the following equation, where *I* stands for electric current.

#### Ohm's Law

**current** (in amperes) = -

voltage difference (in volts)

resistance (in ohms)

$$I = \frac{V}{R}$$

Ohm's law provides a way to measure the resistance of objects and materials. First, the equation above is written as:

$$R = \frac{V}{I}$$

An object is connected to a source of voltage difference and the current flowing in the circuit is measured. The object's resistance then equals the voltage difference divided by the measured current.



Current and the Human
Body When an electric
shock occurs, an electric
current moves through
some part of the body.
The damage caused by an
electric shock depends on
how large the current is.
Research the effects of current on the human body.
Make a table showing the
effects on the body at different amounts of current.

## section 2 review

## **Summary**

## **Current and Voltage Difference**

- Electric current is the net movement of electric charge in a single direction.
- A voltage difference is related to the force that causes charges to flow.
- A circuit is a closed, conducting path.

#### **Batteries**

- Chemical reactions in a battery produce a voltage difference between the positive and negative battery terminals.
- Two commonly used types of batteries are dry-cell batteries and wet-cell batteries.

#### **Resistance and Ohm's Law**

- Resistance is the tendency of a material to oppose the flow of electrons.
- Ohm's law relates the current, *I*, resistance, *R*, and voltage difference, *V*, in a circuit:

$$I = \frac{V}{R}$$

## **Self Check**

- **1. Compare and contrast** a current traveling through a circuit with a static discharge.
- **2. Explain** how a carbon-zinc dry cell produces a voltage difference between the positive and negative terminals.
- Identify two ways to increase the current in a simple circuit.
- **4. Compare and contrast** the flow of water in a pipe and the flow of electrons in a wire.
- Think Critically Explain how the resistance of a lightbulb filament changes after the light has been turned on.

## **Applying Math**

- **6. Calculate** the voltage difference in a circuit with a resistance of 25 ohms if the current is 0.5 A.
- **7. Calculate Resistance** A current of 0.5 A flows in a 60-W lightbulb when the voltage difference between the ends of the filament is 120 V. What is the resistance of the filament?



## Identifying Conduct grs and Insulators

When an insulator is connected in a circuit, only a small current flows. As a result, a lightbulb connected in a circuit with an insulator usually will not glow. In this lab, you will use the brightness of a lightbulb to identify conductors and insulators.



What materials are conductors and what materials are insulators?

#### Goals

- Identify conductors and insulators.
- Describe the common characteristics of conductors and insulators.

#### Materials

battery flashlight bulb bulb holder insulated wire

## Safety Precautions 🗪 🍱 🛣







## Procedure •

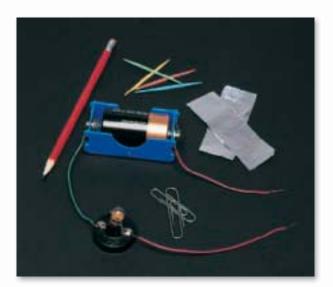
- 1. Complete the safety form before you begin.
- 2. Set up an open circuit as shown above.
- Touch the free bare ends of the wires to various objects around the room. Test at least 12 items.
- 4. Copy the table below. In your table, record which materials make the lightbulb glow and which don't.

#### **Material Tested with Lightbulb Circuit**

**Lightbulb Glows** 

Lightbulb Doesn't Glow

Do not write in this book.



## **Conclude and Apply**

- 1. Is there a pattern to your data?
- 2. Do all or most of the materials that light the lightbulb have something in common?
- 3. Do all or most of the materials that don't light the lightbulb have something in common?
- **4. Explain** why one material might allow the lightbulb to light and another might prevent the lightbulb from lighting.
- 5. **Predict** what other materials will allow the lightbulb to light and what will prevent the lightbulb from lighting.
- **6. Classify** all the materials you have tested as conductors or insulators.



Compare your conclusions with those of other students in your class. For more help, refer to the Science Skill Handbook.



## **Electrical Energy**

## **Reading Guide**

## What You'll Learn

- **Describe** the difference between series and parallel circuits.
- **Recognize** the function of circuit breakers and fuses.
- **Calculate** electrical power.
- **Calculate** the electrical energy used by a device.

## Why It's Important

When you use an electric appliance, such as a hair dryer or a toaster oven, you pay for the electrical energy you use.

## Review Vocabulary

energy: the ability to cause change

### **New Vocabulary**

- series circuit
- parallel circuit
- electrical power

## **Series and Parallel Circuits**

Look around. How many electrical devices such as lights, clocks, stereos, and televisions do you see that are plugged into electrical outlets? Circuits usually include three components. One is a source of voltage difference that can be provided by a battery or an electrical outlet. Another is one or more devices that use electrical energy. Circuits also include conductors such as wires that connect the devices to the source of voltage difference to form a closed path.

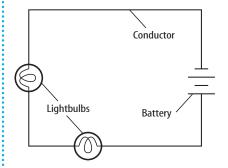
Think about using a hair dryer. The dryer must be plugged into an electrical outlet to operate. A generator at a power plant produces a voltage difference across the outlet, causing charges to move when the circuit is complete. The dryer and the circuit in the house contain conducting wires to carry current. The hair dryer turns the electrical energy into thermal energy and mechanical energy. When you unplug the hair dryer or turn off its switch, you open the circuit and break the path of the current. To use electrical energy, a complete circuit must be made. There are two kinds of circuits.

**Series Circuits** One kind of circuit is called a series circuit. In a series circuit, the current has only one loop to flow through, as shown in **Figure 16.** Series circuits are used in flashlights and some holiday lights.

Reading Check How many loops are in a series circuit?

**Figure 16** A series circuit provides only one path for the current to follow.

**Infer** What happens to the brightness of each bulb as more bulbs are added?







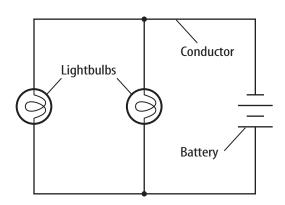
Electrician The installation of electrical wiring in any building usually requires an electrician. Electricians must have a thorough understanding of electricity. They also must constantly be aware of the safety issues involved in working with electricity. Write a paragraph describing other skills that electricians must have.

**Open Circuits** If you have ever decorated a window or a tree with a string of lights, you might have had the frustrating experience of trying to find one burned-out bulb. How can one faulty bulb cause the whole string to go out? Because the parts of a series circuit are wired one after another, the amount of current is the same through every part. When any part of a series circuit is disconnected, no current flows through the circuit. This is called an open circuit. The burned-out bulb causes an open circuit in the string of lights.

**Parallel Circuits** What would happen if your home were wired in a series circuit and you turned off one light? This would cause an open circuit, and all the other lights and appliances in your home would go out, too. This is why houses are wired with parallel circuits. Parallel circuits contain two or more branches for current to move through. Look at the parallel circuit in **Figure 17.** The current can flow through both or either of the branches. Because all branches connect the same two points of the circuit, the voltage difference is the same in each branch. Then, according to Ohm's law, more current flows through the branches that have lower resistance.

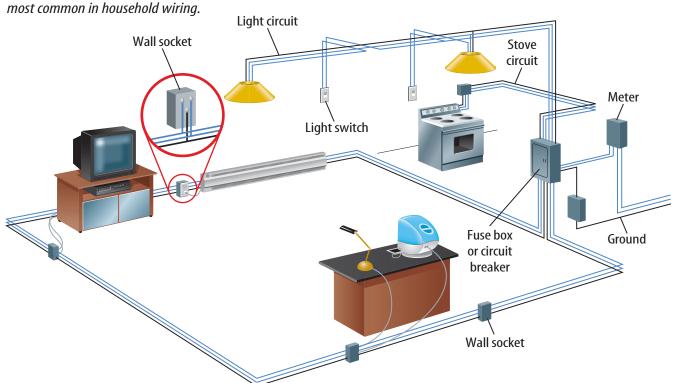
Parallel circuits have several advantages. When one branch of the circuit is opened, such as when you turn a light off, the current continues to flow through the other branches. Houses, automobiles, and most electrical systems use parallel wiring so individual parts can be turned off without affecting the entire circuit.

**Figure 17** In parallel circuits, the current follows more than one path. **Describe** how the voltage difference will compare in each branch.





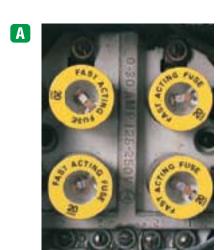
**Figure 18** The wiring in a house must allow for the individual use of various appliances and fixtures. **Identify** the type of circuit that is



## **Household Circuits**

Count how many different things in your home require electrical energy. You don't see the wires because most of them are hidden behind the walls, ceilings, and floors. This wiring is mostly a combination of parallel circuits connected in an organized and logical network. Figure 18 shows how electrical energy enters a home and is distributed. In the United States, the voltage difference in most of the branches is 120 V. In some branches that are used for electric stoves or electric clothes dryers, the voltage difference is 240 V. The main switch and circuit breaker or fuse box serve as an electrical headquarters for your home. Parallel circuits branch out from the breaker or fuse box to wall sockets, major appliances, and lights.

In a house, many appliances draw current from the same circuit. If more appliances are connected, more current will flow through the wires. As the amount of current increases, so does the amount of heat produced in the wires. If the wires get too hot, the insulation can melt and the bare wires can cause a fire. To protect against overheating of the wires, all household circuits contain either a fuse or a circuit breaker.



**Figure 19** Two useful devices to prevent electric circuits from overheating are **A** fuses and **B** circuit breakers. **Evaluate** which device, a fuse or a circuit breaker, would be more convenient to have in the home.



**Figure 20** All appliances come with a power rating.



**Fuses** When you hear that somebody has "blown a fuse," it means that the person has lost his or her temper. This expression comes from the function of an electrical fuse, shown in **Figure 19A**, which contains a small piece of metal that melts if the current becomes too high. When it melts, it causes a break in the circuit, stopping the flow of current through the over-

loaded circuit. To enable current to flow again in the circuit, you must replace the blown fuse with a new one. However, before you replace the blown fuse, you should turn off or unplug some of the appliances. Too many appliances in use at the same time is the most likely cause of the overheating of the circuit.

**Circuit Breaker** A circuit breaker, shown in **Figure 19B**, is another device that prevents a circuit from overheating and causing a fire. A circuit breaker contains a piece of metal that bends when the current in it is so large that it gets hot. The bending causes a switch to flip and open the circuit, stopping the flow of current. Circuit breakers usually can be reset by pushing the switch to its "on" position. Again, before you reset a circuit breaker, you should turn off or unplug some of the appliances from the overloaded circuit. Otherwise, the circuit breaker will switch off again.



What is the purpose of fuses and circuit breakers in household circuits?

### **Electrical Power**

The reason why electricity is so useful is that electrical energy is converted easily to other types of energy. For example, electrical energy is converted to mechanical energy as the blades of a fan rotate to cool you. Electrical energy is converted to light energy in lightbulbs. A hair dryer changes electrical energy into thermal energy. The rate at which electrical energy is converted to another form of energy is the **electrical power**.

The electrical power used by appliances varies. Appliances often are labeled with a power rating that describes how much power the appliance uses, as shown in **Figure 20.** Appliances that have electric heating elements, such as ovens and hair dryers, usually use more electrical power than other appliances.

**Calculating Electrical Power** The electrical power used depends on the voltage difference and the current. Electrical power can be calculated from the following equation.

#### **Electrical Power Equation**

electrical power (in watts) = current (in amperes)  $\times$ **voltage difference** (in volts) P = IV

The unit for power is the watt (W). Because the watt is a small unit of power, electrical power is often expressed in kilowatts (kW). One kilowatt equals 1,000 watts.

#### **Applying Math**

#### **Solve a Simple Equation**

**POWER USED BY A CLOTHES DRYER** The current in an electric clothes dryer is 15 A when it is plugged into a 240-V outlet. How much power does the clothes dryer use?

**IDENTIFY** known values and the unknown value

Identify the known values:

current in the clothes dryer is 15 A means  $I = 15 \, \text{A}$ 

> plugged into a 240-V outlet means V = 240 V

Identify the unknown value:

how much power does the clothes dryer use means

SOLVE the problem

Substitute the known values I = 15 A and V = 240 V into the electrical power equation:

P = IV = (15 A)(240 V) = 3,600 W = 3.6 kW

**CHECK** the answer

Does your answer seem reasonable? Check your answer by dividing the power you calculated by the current given in the problem. The result should be the voltage difference given in the problem.

#### **Practice Problems**

- **1.** A toaster oven is plugged into an outlet that provides a voltage difference of 120 V. What power does the oven use if the current is 10 A?
- 2. A VCR that is not playing still uses 10.0 W of power. What is the current if the VCR is plugged into a 120-V electrical outlet?
- 3. A flashlight bulb uses 2.4 W of power when the current in the bulb is 0.8 A. What is the voltage difference?

For more practice problems go to page 879, and visit Math Practice at gpescience.com.



#### **Topic: Energy**

Visit **gpescience.com** for Web links to information about the cost of electrical energy around the country.

**Activity** Using a blank map of the United States, create a key showing the relative energy costs in different states in different colors. With a partner, color in the states to create a visual map of energy costs. Give your map a title.

**Electrical Energy** Using electrical power costs money. However, electric companies charge by the amount of electrical energy used rather than by the electrical power used. Electrical energy usually is measured in units of kilowatt-hours (kWh) and can be calculated from this equation:

#### **Electrical Energy Equation**

electrical energy (in kWh) = electrical power (in kW) 
$$\times$$
 time (in hours)
$$E = Pt$$

In the above equation, electrical power is in units of kW and the time is the number of hours that the electrical power is used.

## **Applying Math**

#### **Solve a Simple Equation**

**ELECTRICAL ENERGY USED BY A MICROWAVE OVEN** A microwave oven with a power rating of 1,200 W is used for 0.25 h. How much electrical energy is used by the microwave oven?

#### **IDENTIFY** known values and the unknown value

Identify the known values:

power rating of 1,200 W means 
$$P = 1,200 \text{ W} = 1.2 \text{ kW}$$
  
is used for 0.25 h means  $t = 0.25 \text{ h}$ 

#### Identify the unknown value:

how much electrical energy is used means E = ? kWh

#### **SOLVE** the problem

Substitute the known values p = 1.2 kW and t = 0.25 h into the electrical energy equation:

$$E = Pt = (1.2 \text{ kW})(0.25 \text{ h}) = 0.30 \text{ kWh}$$

#### **CHECK** your answer

Does your answer seem reasonable? Check your answer by dividing the electrical energy you calculated by the power given in the problem. The results should be the time given in the problem.

#### **Practice Problems**

- 1. A refrigerator operates on average for 10.0 h a day. If the power rating of the refrigerator is 700 W, how much electrical energy does the refrigerator use in one day?
- 2. A TV with a power rating of 200 W uses 0.8 kWh in one day. For how many hours was the TV on during this day?

For more practice problems go to page 879, and visit Math Practice at gpescience.com.

#### The Cost of Using Electrical Energy

The cost of using an appliance can be computed by multiplying the electrical energy used by the amount the power company charges for each kWh. For example, if a 100-W lightbulb is left on for 5 h, the amount of electrical energy used is

$$E = Pt = (0.1 \text{ kW})(5 \text{ h}) = 0.5 \text{ kWh}$$

If the power company charges \$0.10 per kWh, the cost of using the bulb for 5 h is

$$cost = (kWh used)(cost per kWh)$$
  
=  $(0.5 kWh)(\$0.10/kWh) = \$0.05$ 

The cost of using some household appliances is given in **Table 1**, where the cost per kWh is assumed to be \$0.09/kWh.

Table 1 Cost of Using Home Appliances				
Appliance	Hair Dryer	Stereo	Color Television	
Power rating	1,000	100	200	
Hours used daily	0.25	2.0	4.0	
kWh used monthly	7.5	6.0	24.0	
Cost per kWh	\$0.09	\$0.09	\$0.09	
Monthly cost	\$0.68	\$0.54	\$2.16	

## section

#### review

#### **Summary**

#### **Series and Parallel Circuits**

- A series circuit has only one path that current can follow. A parallel circuit has two or more branches that current can follow.
- Household wiring usually consists of a number of connected parallel circuits.
- Fuses and circuit breakers are used to prevent wires from overheating when the current in the wires becomes too large.

#### **Electrical Power**

- Electrical power is the rate at which electrical energy is converted into other forms of energy.
- Electrical power can be calculated by multiplying the current by the voltage difference:

$$P = IV$$

#### **Electrical Energy**

• The electrical energy used can be calculated by multiplying the power by the time:

$$E = Pt$$

 Electric power companies charge customers for the amount of electrical energy they use.

#### Self Check

- 1. Explain how electrical power and electrical energy are related.
- 2. Discuss why fuses and circuit breakers are used in household circuits.
- 3. Explain what determines the current in each branch of a parallel circuit.
- **4. Explain** whether or not a fuse or circuit breaker should be connected in parallel to the circuit it is protecting.
- 5. Think Critically A parallel circuit consisting of four branches is connected to a battery. Explain how the amount of current that flows out of the battery is related to the amount of current in the branches of the circuit.

#### **Applying Math**

- **6. Calculate** the current flowing into a desktop computer plugged into a 120-V outlet if the power used is 180 W.
- 7. Calculate Electrical Power A circuit breaker is tripped when the current in the circuit is greater than 15 A. If the voltage difference is 120 V, what is the power being used when the circuit breaker is tripped?
- 8. Calculate the monthly cost of using a 700-W refrigerator that runs for 10 h a day if the cost per kWh is \$0.09.



# **Design Your Own**

#### Goals

- **Design** and construct series and parallel circuits.
- **Compare** and contrast the behaviors of series and parallel circuits.

#### **Possible Materials**

6-V dry-cell battery small lights with sockets (3) aluminum foil paper clips tape scissors paper

#### **Safety Precautions**





Some parts of circuits can become hot. Do not leave the battery connected or the circuit closed for more than a few seconds at a time. Never connect the positive and negative terminals of the dry-cell battery directly without including at least one bulb in the circuit.

# Comparing Series and Parallel Circuits

#### **Real-World Problem**

Imagine what a bedroom might be like if it were wired in series. For an alarm clock to keep time and wake you in the morning, your lights and anything else that uses electricity would have to be on. Fortunately, most outlets in homes are wired in parallel circuits on separate branches of the main circuit. How do the behaviors of series and parallel circuits compare?



# Form a Hypothesis

Predict what will happen to the other bulbs when one bulb is unscrewed from a series circuit and from a parallel circuit. Explain your prediction. Also, form a hypothesis to explain in which circuit the lights shine the brightest.



# Using Scientific Methods

# Test Your Hypothesis

#### Make a Plan

- 1. Complete the safety form before you begin.
- **2.** As a group, agree upon and write the hypothesis statement.
- **3.** Work together to determine and write the steps you will take to test your hypothesis. Include a list of the materials you will need.
- **4.** How will your circuits be arranged? On a piece of paper, draw a large parallel circuit of three lights and the dry-cell battery as shown. On the other side, draw another circuit with the three bulbs arranged in series.
- **5.** Make conducting wires by taping a piece of transparent tape to a sheet of aluminum foil and folding the foil over twice to cover the tape. Cut these to any length that works in your design.



- 1. Make sure your teacher approves your plan before you start.
- **2.** Carry out the experiment. **WARNING:** *Leave the circuit on for only a few seconds at a time to avoid overheating.*
- **3.** As you do the experiment, record your predictions and your observations in your Science Journal.

# Analyze Your Data

- 1. **Predict** what will happen in the series circuit when a bulb is unscrewed at one end. What will happen in the parallel circuit?
- **2. Compare** the brightness of the lights in the different circuits. Explain.
- **3. Predict** what will happen to the brightness of the bulbs in the series circuit if you complete it with two bulbs instead of three bulbs. Test your prediction. How do the results demonstrate Ohm's law?

# Conclude and Apply

- 1. Did the results support your hypothesis? Explain by using your observations.
- 2. Where in the parallel circuit would you place a switch to control all three lights? Where would you place a switch to control only one light? Test your predictions.



**Prepare** a poster to highlight the differences between a parallel and a series circuit. Include possible practical applications of both types of circuits. For more help, refer to the Science Skill Handbook.

# Science Language

# Invisible Man

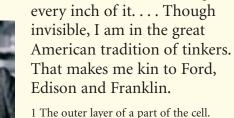
by Ralph Ellison

I am an invisible man. No, I am not a spook like those who haunted Edgar Allan Poe; nor am I one of your Hollywood-movie ectoplasms. 1 I am a man of substance, of flesh and bone, fiber and liquids—and I might even be said to possess a mind. I am invisible, understand, simply because people refuse to see me.... Nor is my invisibility exactly a matter of biochemical accident to my epidermis.<sup>2</sup> That invisibility to which I refer occurs because of a peculiar disposition . . . of those with whom I come in contact. . . .

.... Now don't jump to the conclusion that because I call my home a "hole" it is damp and cold like a grave. . . . Mine is a warm hole.

My hole is warm and full of light. Yes, full of light. I doubt if there is a brighter spot in all New York than this hole of mine. . . . Perhaps you'll think it strange that an invisible man should need light, desire light, love light. Because maybe it is exactly because I am invisible. Light confirms my reality, gives birth to my form. . . . I myself, after existing some twenty years, did not become alive until I discovered my invisibility.

... In my hole in the basement there are exactly 1,369 lights. I've wired the entire ceiling,



- 2 The outer layer of skin.



Ralph Ellison

## **Understanding** Literature

**Prologue** A prologue is an introduction to a novel, play, or other work of literature. Often a prologue contains useful information about events to come in the story. Foreshadowing is the use of clues by the author to prepare readers for future events or recurring themes.

#### Respond to the Reading

- 1. What clues does the narrator give that he is not really invisible?
- 2. Why does the narrator believe he is in the "great American tradition of tinkers"?
- 3. Linking Science and Writing Write a prologue to a fictional book describing Edison's invention of the lightbulb. Recall that a prologue is not a summary of the book. Rather, it can state general themes that the work of literature will address or set the stage or describe the setting of the story.



If all 1,369 light-bulbs were wired together

in a series circuit, the electrical resistance in the circuit would be high. According to Ohm's law, the current in the circuit would be low and the bulbs wouldn't glow. If all the bulbs were wired in a parallel circuit, so much current would flow in the circuit that the connecting wires would melt. For the bulbs to light, the narrator must have wired them in many independent circuits.

# **Reviewing Main Ideas**

#### **Section 1 Electric Charge**

- **1.** There are two types of electric charge: positive charge and negative charge.
- **2.** Electric charges exert forces on each other. Like charges repel and unlike charges attract.



- **3.** Electric charges can be transferred from one object to another but cannot be created or destroyed.
- **4.** Electrons can move easily in an electrical conductor. Electrons do not move easily in an insulator.
- **5.** Objects can be charged by contact or by induction. Charging by induction occurs when a charged object is brought near an electrically neutral object.

#### Section 2

#### **Electric Current**

- 1. Electric current is the net movement of electric charges in a single direction. A voltage difference causes an electric current to flow.
- **2.** A circuit is a closed path along which charges can move. Current will flow continually only along a circuit that is unbroken.
- **3.** Chemical reactions in a battery produce a voltage difference between the positive and negative terminals of the battery.

- **4.** Electrical resistance is the tendency of a material to oppose the flow of electric current.
- **5.** In an electric circuit, the voltage difference, current, and resistance are related by Ohm's law:

$$I = \frac{V}{R}$$

#### **Section 3 Electrical Energy**

- **1.** Current has only one path in a series circuit and more than one path in a parallel circuit.
- **2.** Circuit breakers and fuses prevent excessive current from flowing in a circuit.
- **3.** Electrical power is the rate at which electrical energy is used and can be calculated with P = IV.
- **4.** The electrical energy used by a device can be calculated with the equation E = Pt.



FOLDABLES Use the Foldable you made at the beginning of the chapter to help you review electric charge, electric current, and electrical energy.

#### **Using Vocabulary**

charging by contact p. 395 charging by induction p. 396 circuit p. 401 conductor p. 395 electric current p. 400 electrical power p. 410 insulator p. 395 law of conservation of charge p. 393 Ohm's law p. 405 parallel circuit p. 408 resistance p. 403 series circuit p. 407 static electricity p. 392 voltage difference p. 400

Complete each statement using a word(s) from the vocabulary list above.

- **1.** A(n) \_\_\_\_\_ is a circuit with only one path for current to follow.
- **2.** An accumulation of excess electric charge is .
- **3.** The electric force that makes current flow in a circuit is related to the
- **4.** According to \_\_\_\_\_\_, electric charge cannot be created or destroyed.
- 5. \_\_\_\_\_ is the result of electrons colliding with atoms as current flows in a material.
- **6.** Charging a balloon by rubbing it on wool is an example of \_\_\_\_\_.

#### **Checking Concepts**

Choose the word or phrase that best answers the question.

- **7.** Which of the following is a conductor?
  - A) glass
- **C)** tungsten
- **B)** wood
- **D)** plastic
- **8.** Resistance in wires causes electrical energy to be converted into which form of energy?
  - A) chemical energy
  - **B)** nuclear energy
  - **c)** thermal energy
  - **D)** sound

- **9.** The electric force between two charged objects depends on which of the following?
  - A) their masses and their separation
  - **B)** their speeds
  - c) their charge and their separation
  - **D)** their masses and their charge
- **10.** An object becomes positively charged when which of the following occurs?
  - **A)** loses electrons
- **c)** gains electrons
- **B)** loses protons
- **D)** gains neutrons
- **11.** Which of the following does NOT provide a voltage difference in a circuit?
  - **A)** wet cell
- c) electrical outlet
- **B)** wires
- **D)** dry cell
- **12.** A commonly used unit for electrical energy is which of the following?
  - **A)** kilowatt-hour
- c) ohm
- B) ampere
- **D)** newton
- **13.** Which of the following is the rate at which appliances use electrical energy?
  - **A)** power
- c) resistance
- **B)** current
- **D)** speed

#### Interpreting Graphics

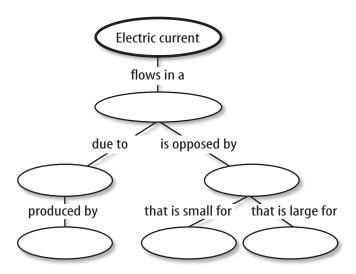
Use the table below to answer question 14.

Current in Electric Circuits			
Circuit	Current (A)		
А	2.3		
В	0.6		
C	0.2		
D	1.8		

14. The table shows the current in circuits that were each connected to a 6-V dry cell. Calculate the resistance of each circuit. Graph the current versus the resistance of each circuit. Describe the shape of the line on your graph.

# chapter 13 Review

**15.** Copy and complete the following concept map on electric current.



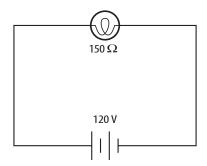
#### **Thinking Critically**

- **16. Identify and Manipulate Variables** Design an experiment to test the effect on current and voltage differences in a circuit when two identical batteries are connected in series. What is your hypothesis? What are the variables and controls?
- **17. Explain** A metal rod is charged by induction when a negatively charged plastic rod is brought nearby. Explain how the net charge on the metal rod has changed.
- **18. Predict** You walk across a carpet on a dry day and touch a glass doorknob. Predict whether or not you would receive an electric shock. Explain your reasoning.
- 19. Explain The electric force between electric charges is much larger than the gravitational force between the charges. Why, then, is the gravitational force between Earth and the Moon much larger than the electric force between Earth and the Moon?

20. Diagram Draw a circuit diagram showing how a stereo, a TV, and a computer can be connected to a single source of voltage difference, such that turning off one appliance does not turn off all the others. Include a circuit breaker in your diagram that will protect all the appliances.

#### **Applying Math**

**21. Calculate Current** Using the information in the circuit diagram below, compute the current flowing in the circuit.



- **22.** Calculate Current A toy car with a resistance of  $20 \Omega$  is connected to a 3-V battery. How much current flows in the car?
- **23. Calculate Electrical Energy** The current flowing in an appliance connected to a 120-V source is 2 A. How many kilowatt-hours of electrical energy does the appliance use in 4 h?
- **24. Calculate Electrical Energy Cost** A self-cleaning oven uses 5,400 W when cleaning itself. If it takes 1.5 h to clean, how many kilowatt-hours of electricity are used? At a cost of \$0.09 per kWh, what does it cost to clean the oven?
- **25. Calculate Power** A calculator uses a 9-V battery and draws 0.1 A of current. How much power does it use?

# chapter 13 Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### **Multiple Choice**

- **1.** Which of the following is true about two adjacent electric charges?
  - **A.** If both are positive, they attract.
  - **B.** If both are negative, they attract.
  - **c.** If one is positive and one is negative, they attract.
  - **D.** If one is positive and one is negative, they repel.

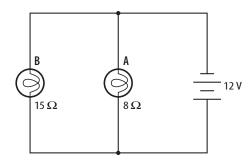
The figure below shows a negatively charged electroscope. Use the figure to answer questions 2 and 3.



- **2.** If a negatively charged rod is brought close to, but not touching, the knob, the two leaves will
  - **A.** move closer together.
  - **B.** move farther apart.
  - **c.** not move at all.
  - **D.** become positively charged.
- **3.** If a positively charged rod touches the knob, the two leaves will
  - **A.** move closer together.
  - **B.** move farther apart.
  - **c.** not move at all.
  - **D.** become positively charged.

- **4.** When an object becomes charged by induction, which of the following best describes the net charge on the object?
  - **A.** The net charge increases.
  - **B.** The net charge decreases.
  - **c.** The net charge doesn't change.
  - **D.** The net charge is negative.

Use the figure below to answer questions 5, 6, and 7.

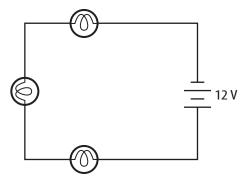


- **5.** Which of the following is the same for each lightbulb?
  - **A.** current in the filament
  - **B.** voltage difference
  - **C.** electric resistance
  - **D.** charging by induction
  - **6.** Which of the following is the current that flows through lightbulb B?
    - **A.** 1.25 A
    - **B.** 0.67 A
    - **c.** 0.8 A
    - **D.** 1.5 A

- **7.** Which of the following is the electrical power used by lightbulb A?
  - **A.** 8 W
  - **B.** 18 W
  - **c.** 12 W
  - **D.** 15 W

#### **Gridded Response**

Use the figure below to answer questions 8 and 9.



- **8.** If the current in the circuit is 1.0 A, what is the total resistance of the circuit in ohms?
- **9.** If the current in the circuit is 1.0 A, how much electrical energy, in kWh, is used by the circuit in 2.5 h?

## **Short Response**

**10.** Two balloons are rubbed with a piece of wool. Describe what happens as the balloons are brought close together.

**11.** The current flowing through a lightbulb is 2.5 A. The lamp is connected to a battery supplying a voltage difference of 12 V. What is the power used by the lightbulb?

#### **Extended Response**

Use the table below to answer question 12.

Resistance of Copper Wire		
Length (m)	Resistance ( $\Omega$ )	
10	0.8	
20	1.6	
25	2.0	
30	2.4	

- **12.** Suppose you were asked to estimate the resistance of a 5-m length of wire based on data in the table. What additional information would be needed to make your estimate more accurate?
- **13.** The filament in a 75-W lightbulb has a smaller electric resistance than the filament in a 40-W lightbulb. Describe two ways the filament in the 75-W bulb could be different from the filament in the 40-W lightbulb.

#### Test-Taking Tip

Be sure you understand all symbols on a table or graph before attempting to answer any questions about the table or graph.

# chapter 14

#### BIG (Idea

A magnet is surrounded by a magnetic field that exerts a force on other magnets.

#### 14.1 Magnetism

MAIN (Idea Like magnetic poles repel each other and unlike poles attract each other.

# 14.2 Electricity and Magnetism

MAIN (Idea An electric current in a wire is surrounded by a magnetic field.

# 14.3 Producing Electric Current

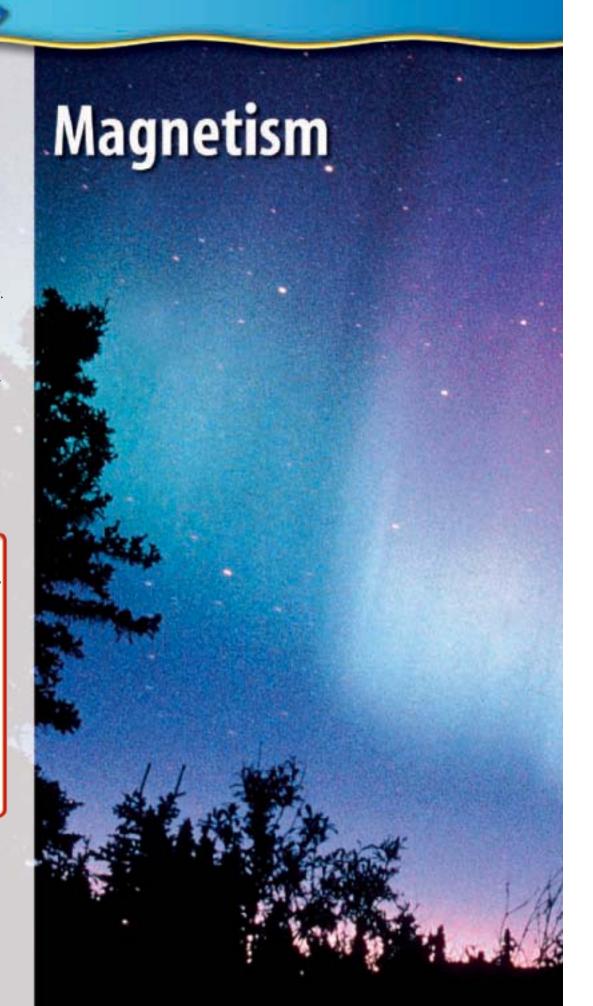
MAIN (Idea A changing magnetic field can produce an electric current in a wire loop.

#### A Natural Light Show

Have you ever seen an aurora? Auroras result when the Sun emits a blast of charged particles. These blasts cause charged particles trapped by Earth's magnetic field to collide with atoms in the upper atmosphere. The light you see as an aurora is emitted as these collisions occur.

#### **Science Journal**

List three things you know about magnets.



# **Start-Up Activities**



#### **The Strength of Magnets**

Did you know that magnets are used in TV sets, computers, stereo speakers, electric motors, and many other devices? Magnets also help create images of the inside of the human body. Even Earth acts like a giant bar magnet. How do magnets work?

- 1. Complete the safety form.
- 2. Hold a bar magnet horizontally and put a paper clip on one end. Touch a second paper clip to the end of the first one. Continue adding paper clips until none will stick to one end of the chain. Copy the data table below and record the number of paper clips the magnet holds. Remove the paper clips from the magnet.
- 3. Repeat step 2 three more times. First, start the chain about 2 cm from the end of the magnet. Second, start the chain near the center of the magnet. Third, start the chain at the other end of the magnet.
- 4. Think Critically Infer which part of the magnet exerts the strongest attraction. Compare the attraction at the center of the magnet with the attraction at the ends.

#### **Magnet and Paper Clip Data**

	· •
	Paper Clip Chain (number of clips)
Trial 1 (end)	
Trial 2 (2 cm)	
Trial 3 (center)	
Trial 4 (other end)	



**Using Magnets** Many devices you use contain magnets that help convert one form of energy

to another. Make the following Foldable to help you understand how magnets are used to transform electrical and mechanical energy.

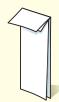
STEP 1

**Fold** a sheet of paper in half lengthwise.



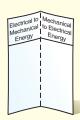
STEP 2

Fold the paper down about 2 cm from the top.



STEP 3

Open and draw lines along the top fold. Label as shown.



**Summarize** As you read the chapter, summarize how magnets are used to convert electrical energy to mechanical energy in the left column, and how magnets are used to convert mechanical energy to electrical energy in the right column.



Preview this chapter's content and activities at qpescience.com

# Magnetism

### **Reading Guide**

#### What You'll Learn

- **Explain** how a magnet exerts a force.
- Describe the properties of temporary and permanent magnets.
- **Explain** why some materials are magnetic and some are not.
- Model magnetic behavior using magnetic domains.

# Why It's Important

Without the forces exerted by magnets, you could not use televisions, computers, CD players, or even refrigerators.

#### Review Vocabulary

**electric field:** surrounds an electric charge and exerts a force on other electric charges

#### **New Vocabulary**

- magnetism
- magnetic field
- magnetic pole
- magnetic domain

# **Magnets**

More than 2,000 years ago, Greeks discovered deposits of a mineral that was a natural magnet. They noticed that chunks of this mineral could attract pieces of iron. This mineral was found in a region of Turkey that then was known as Magnesia, so the Greeks called the mineral magnetic. The mineral is now called magnetite. In the twelfth century, Chinese sailors used magnetite to make compasses that improved navigation. Since then, many devices have been developed that rely on magnets to operate. Today, the word **magnetism** refers to the properties and interactions of magnets. Figure 1 shows a device you might be familiar with that uses magnets and magnetism.

**Magnetic Force** You probably have played with magnets and noticed that two magnets exert a force on each other. Depending on which ends of the magnets are close together, magnets either repel or attract each other. You might have noticed that the interaction between two magnets can be felt even before the magnets touch. The strength of the force between two magnets increases as magnets move closer together and decreases as the the magnets move farther apart.



Figure 1 Magnets can be found in many devices you use every day, such as TVs, video games, and telephones. Headphones and CD players also contain magnets.

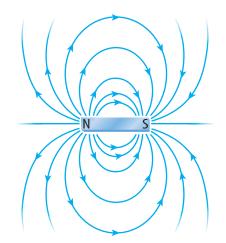


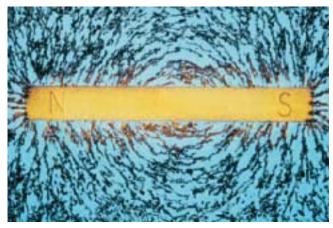
What does the force between two magnets depend on?

**Figure 2** A magnet is surounded by a magnetic field.

A magnet's magnetic field is represented by magnetic field

lines.



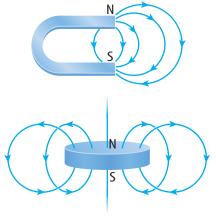


Iron filings sprinkled around a magnet line up along the magnetic field lines.

**Magnetic Field** A magnet is surrounded by a magnetic field. A magnetic field exerts a force on other magnets and objects made of magnetic materials. The magnetic field is strongest close to the magnet and weaker farther away. The magnetic field can be represented by lines of force, or magnetic field lines. **Figure 2** shows the magnetic field lines surrounding a bar magnet. A magnetic field also has a direction. The direction of the magnetic field around a bar magnet is shown by the arrows on the left side of Figure 2.

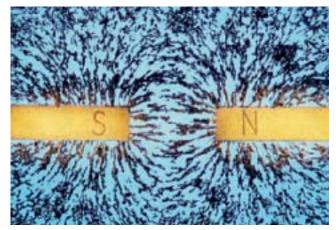
**Magnetic Poles** Look again at **Figure 2.** Do you notice that the magnetic field lines are closest together at the ends of the bar magnet? These regions, called the magnetic poles, are where the magnetic force exerted by the magnet is strongest. All magnets have a north pole and a south pole. For a bar magnet, the north and south poles are at the opposite ends.

Figure 3 shows the north and south poles of magnets with more complicated shapes. The two ends of a horseshoe-shaped magnet are the north and south poles. A magnet shaped like a disk has opposite poles on the top and bottom of the disk. Magnetic field lines always connect the north pole and the south pole of a magnet.



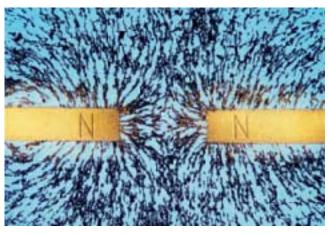
**Figure 3** The magnetic field lines around horseshoe and disk magnets begin at each magnet's north pole and end at the south pole.

**Identify** where the magnetic field is strongest.



Unlike poles closest together

**Figure 4** Two magnets can attract or repel each other, depending on which poles are closest together.

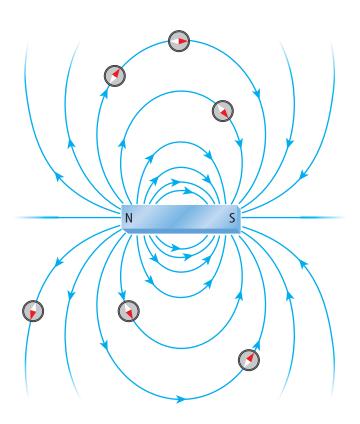


Like poles closest together

**How Magnets Interact** Two magnets can either attract or repel each other. Two north poles or two south poles of two magnets repel each other. However, north poles and south poles always attract each other. Like magnetic poles repel each other and unlike poles attract each other. When two magnets are brought close to each other, their magnetic fields combine to produce a new magnetic field. **Figure 4** shows the magnetic field that results when like poles and unlike poles of bar magnets are brought close to each other.



Reading Check How do magnetic poles interact with each other?



Magnetic Field Direction When a compass is brought near a bar magnet, the compass needle rotates. The compass needle is a small bar magnet with a north pole and a south pole. The force exerted on the compass needle by the magnetic field causes the needle to rotate. The compass needle rotates until it lines up with the magnetic field lines, as shown in **Figure 5.** The north pole of a compass points in the direction of the magnetic field. This direction is always away from a north magnetic pole and toward a south magnetic pole.

Figure 5 Compass needles placed around a bar magnet line up along magnetic field lines. The north poles of the compass needles are shaded red.

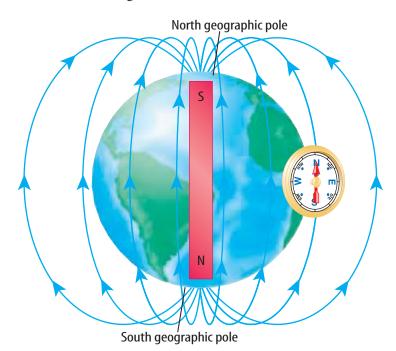
**Earth's Magnetic Field** A compass can help determine direction because the

north pole of the compass needle points north. This is because Earth acts like a giant bar magnet and is surrounded by a magnetic field that extends into space. Just as with a bar magnet, the compass needle aligns with Earth's magnetic field lines, as shown in **Figure 6.** 

**Earth's Magnetic Poles** The north pole of a magnet is defined as the end of the magnet that points toward the geographic north. Sometimes the north pole and south pole of a magnet are called the north-seeking pole and the south-seeking pole. Because opposite magnetic poles attract, the north pole of a compass is being attracted by a south magnetic pole. Earth is like a bar magnet with its south magnetic pole near its geographic north pole.

Currently, Earth's south magnetic pole is located in northern Canada, about 1,500 km from the geographic north pole. However, Earth's magnetic poles move slowly with time. Sometimes Earth's magnetic poles switch places so that Earth's south magnetic pole is in the southern hemisphere near the geographic south pole. Measurements of magnetism in rocks show that Earth's magnetic poles have changed places over 150 times in the past 70 million years.

No one is sure what produces Earth's magnetic field. Earth's inner core is made of a solid ball of iron and nickel, surrounded by a liquid layer of molten iron and nickel. According to one theory, circulation of the molten iron and nickel in Earth's outer core produces Earth's magnetic field.





#### **Observing Magnetic** Interference

#### 

- **1.** Complete the safety form.
- 2. Clamp a bar magnet to a ring stand. Tie a thread around one end of a paper clip and stick the paper clip to one pole of the magnet.
- 3. Anchor the other end of the thread under a **book** on the table. Slowly pull the thread until the paper clip is suspended below the magnet but not touching it.
- 4. Without touching the paper clip, slip a piece of paper between the magnet and the paper clip. Does the paper clip fall?
- **5.** Try other materials, such as aluminum foil, fabric, and a butter knife.

#### **Analysis**

- 1. Which materials caused the paper clip to fall? Why?
- 2. Which materials did not cause the paper clip to fall? Why?

**Figure 6** A compass needle aligns with the magnetic field lines of Earth's magnetic field. **Predict** Which way would a compass needle point if Earth's magnetic poles switched places?



#### Magnets in Organisms

Some organisms may use Earth's magnetic field to help them find their way around. Some species of birds, insects, and bacteria have been shown to contain small amounts of the mineral magnetite. Research how one species uses Earth's magnetic field, and report your findings to your class.

# **Magnetic Materials**

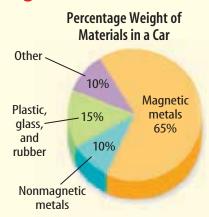
You might have noticed that a magnet will not attract all metal objects. For example, a magnet will not attract pieces of aluminum foil. Only a few metals, such as iron, cobalt, and nickel, are attracted to magnets or can be made into permanent magnets. What makes these elements magnetic? Remember that every atom contains electrons. Electrons have magnetic properties. In the atoms of most elements, the magnetic properties of the electrons cancel out. However, in the atoms of iron, cobalt, and nickel, these magnetic properties don't cancel out. Each atom in these elements behaves like a small magnet and has its own magnetic field.

Even though these atoms have their own magnetic fields, objects made from these metals are not always magnets. For example, if you hold an iron nail close to a refrigerator door and let go, it falls to the floor. However, you can make the nail behave like a magnet temporarily.

### **Applying Science**

#### How can magnetic parts of a junk car be salvaged?

very year over 10 million cars containing plastics, glass, rubber, and various metals are scrapped. Magnets are often used to help retrieve some of these materials from scrapped cars. The materials can then be reused, saving both natural resources and energy. Once the junk car has been fed into a shredder, large magnets can easily separate many of its metal parts from its nonmetal parts. How much of the car does a magnet actually help separate? Use your ability to interpret a circle graph to find out.



#### **Identifying the Problem**

The graph at the right shows the average percent by weight of the different materials in a car. Included in the magnetic metals are steel and iron. The nonmagnetic metals refer to aluminum, copper, lead, zinc, and magnesium. According to the graph, how much of the car can a magnet separate for recycling?

#### Solving the Problem

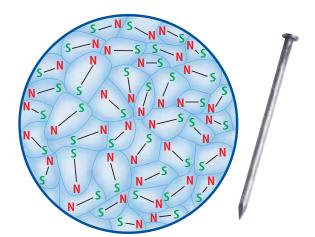
- **1.** What percent of the car's weight will a magnet recover?
- 2. A certain scrapped car has a mass of 1,500 kg. What is the mass of the materials in this car that cannot be recovered using a magnet?
- **3.** If the average mass of a scrapped car is 1,500 kg and 10 million cars are scrapped each year, what is the total mass of iron and steel that could be recovered from scrapped cars each year?

Magnetic Domains—A Model for Magnetism In iron, cobalt, nickel, and some other magnetic materials, the magnetic field created by each atom exerts a force on the other nearby atoms. Because of these forces, large groups of atoms align their magnetic poles so that almost all like poles point in the same direction. The groups of atoms with aligned magnetic poles are called **magnetic domains**. Each domain contains an enormous number of atoms, yet the domains are too small to be seen with the unaided eye. Because the magnetic poles of the individual atoms in a domain are aligned, the domain itself behaves like a magnet with a north pole and a south pole.

**Lining Up Domains** An iron nail contains an enormous number of these magnetic domains, so why doesn't the nail behave like a magnet? Even though each domain behaves like a magnet, the poles of the domains are arranged randomly and point in different directions, as shown in **Figure 7.** As a result, the magnetic fields from all the domains cancel each other out.

If you place a magnet against the same nail, the atoms in the domains orient themselves in the direction of the nearby magnetic field, as shown on the right in Figure 7. The like poles of the domains point in the same direction and no longer cancel each other out. The nail itself now acts as a magnet. However, when the external magnetic field is removed, the constant motion and vibration of the atoms bump the magnetic domains out of their alignment. The magnetic domains in the nail return to a random arrangement. For this reason, the nail is only a temporary magnet. Paper clips and other objects containing iron also can become temporary magnets.

**Figure 7** Magnetic materials contain magnetic domains.



A normal iron nail is made up of microscopic domains that are arranged randomly.



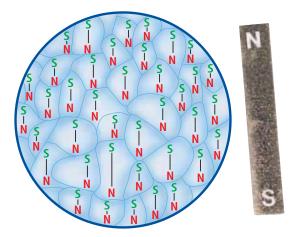
#### **Making Your Own Compass**

Procedure 700 WARNING: Use care when handling sharp objects.

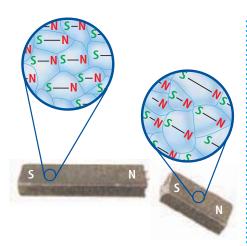
- **1.** Complete the safety form.
- 2. Cut off the bottom of a plastic foam cup to make a polystyrene disk.
- 3. Magnetize a sewing needle by continuously stroking the needle in the same direction with a magnet for 1 min.
- **4. Tape** the needle to the center of the foam disk.
- 5. Fill a plate with water and float the disk, needle-side up, in the water.
- **6.** Bring the magnet close to the foam disk.

#### **Analysis**

- 1. How did the needle and disk move when placed in the water? Explain.
- 2. How did the needle and disk move when the magnet was brought near? Explain.



The domains will align themselves along the magnetic field lines of a nearby magnet.



**Figure 8** Each piece of a broken magnet still has a north and a south pole.

**Permanent Magnets** A permanent magnet can be made by placing a magnetic material, such as iron, in a strong magnetic field. The strong magnetic field causes the magnetic domains in the material to line up. The magnetic fields of these aligned domains combine and create a strong magnetic field inside the material. This field prevents the constant motion of the atoms from bumping the domains out of alignment. The material is then a permanent magnet.

Even permanent magnets can lose their magnetic behavior if they are heated. Heating causes atoms in a magnet to move faster. If a permanent magnet is heated enough, its atoms may be moving fast enough to jostle the domains out of alignment. Then the permanent magnet loses its magnetic field and is no longer a magnet.

**Can a pole be isolated?** What happens when a magnet is broken in two? Can one piece be a north pole and one piece be a south pole? Look at the domain model of the broken magnet in **Figure 8.** Recall that even individual atoms of magnetic materials act as tiny magnets. Because every magnet is made of many aligned smaller magnets, even the smallest pieces have both a north pole and a south pole.

#### section

#### review

#### **Summary**

#### Magnets

- A magnet is surrounded by a magnetic field that exerts a force on magnetic materials.
- A magnet has a north pole and a south pole.
- Like magnetic poles repel and unlike poles attract.

#### **Magnetic Materials**

- Iron, cobalt, and nickel are magnetic elements because their atoms behave like magnets.
- Magnetic domains are regions in a material that contain an enormous number of atoms with their magnetic poles aligned.
- A magnetic field causes domains to align. In a temporary magnet, the domains return to a random alignment when the field is removed.
- In a permanent magnet, a stong magnetic field aligns domains, and they remain aligned when the field is removed.

#### Self Check

- 1. Describe what happens when you move two unlike magnetic poles closer together. Draw a diagram to illustrate your answer.
- **2. Describe** how a compass needle moves when it is placed in a magnetic field.
- **3. Explain** why only certain materials are magnetic.
- 4. Predict how the properties of a bar magnet would change if it were broken in half.
- 5. Explain how heating a bar magnet would change its magnetic field.
- **6. Think Critically** Use the magnetic domain model to explain why a magnet sticks to a refrigerator door.

#### **Applying Math**

7. Calculate Number of Domains The magnetic domains in a magnet have an average volume of 0.0001 mm<sup>3</sup>. If the magnet has dimensions of 50 mm by 10 mm by 4 mm, how many domains does the magnet contain?

# 2

# Electricity and Magnetism

# **Reading Guide**

#### What You'll Learn

- Describe the magnetic field produced by an electric current.
- Explain how an electromagnet produces a magnetic field.
- Describe how electromagnets are used.
- Explain how an electric motor operates.

# Why It's Important

Electric motors contained in many of the devices you use every day operate because electric currents produce magnetic fields.

#### Review Vocabulary

**electric current:** the flow of electric charges in a wire or any conductor

#### **New Vocabulary**

- electromagnet
- solenoid
- galvanometer
- electric motor

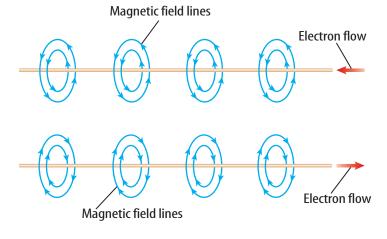
# **Electric Current and Magnetism**

In 1820, Hans Christian Oersted, a Danish physics teacher, found that electricity and magnetism are related. While doing a demonstration involving electric current, he happened to have a compass near an electric circuit. He noticed that the flow of the electric current affected the direction the compass needle pointed. Oersted hypothesized that the electric current must have produced a magnetic field around the wire, and that the direction of the field changed with the direction of the current.

**Moving Charges and Magnetic Fields** Oersted's hypothesis that an electric current creates a magnetic field was correct.

Moving charges, such as those in an electric current, produce magnetic fields. Around a current-carrying wire the magnetic field lines form circles, as shown in **Figure 9.** The direction of the magnetic field around the wire reverses when the direction of the current in the wire reverses. As the current in the wire increases, the strength of the magnetic field increases, the strength of the magnetic field decreases.

**Figure 9** When electric current flows through a wire, a magnetic field forms around the wire. The direction of the magnetic field depends on the direction of the current in the wire.



# **Electromagnets**

The magnetic field that surrounds a current-carrying wire can be made much stronger in an electromagnet. An **electromagnet** is a temporary magnet made by wrapping a wire coil carrying a current around an iron core. When a current flows through a wire loop, such as the one shown in **Figure 10A**, the magnetic field inside the loop is stronger than the field around a straight wire. A single wire wrapped into a cylindrical wire coil is called a **solenoid**. The magnetic field inside a solenoid is stronger than the field in a single loop. The magnetic field around each loop in the solenoid combines to form the field shown in **Figure 10B**.

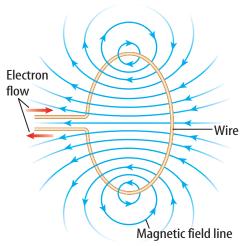
If the solenoid is wrapped around an iron core, an electromagnet is formed, as shown in **Figure 10C.** The solenoid's magnetic field magnetizes the iron core. As a result, the field inside the solenoid with the iron core can be more than 1,000 times greater than the field inside the solenoid without the iron core.

**Properties of Electromagnets** Electromagnets are temporary magnets because a magnetic field is present only when current is flowing in the solenoid. The strength of the magnetic field can be increased by adding more turns of wire to the solenoid or by increasing the current passing through the wire.

An electromagnet behaves like any other magnet when current flows through the solenoid. One end of the electromagnet is a north pole and the other end is a south pole. If it is placed in a magnetic field, an electromagnet will align itself along the magnetic field lines, just as a compass needle will. An electromagnet also will attract magnetic materials and be attracted or repelled by other magnets. What makes an electromagnet so useful is that its magnetic properties can be controlled by changing the electric current flowing through the solenoid.

When current flows in an electromagnet and it moves toward or away from another magnet, electric energy is converted into mechanical energy to do work. Electromagnets do work in various devices, such as stereo speakers and electric motors.

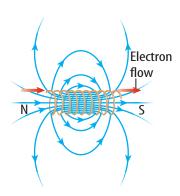
**Figure 10** An electromagnet is made from a current-carrying wire.

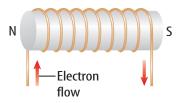


A The magnetic fields around different parts of the wire loop combine to form the field inside the loop.

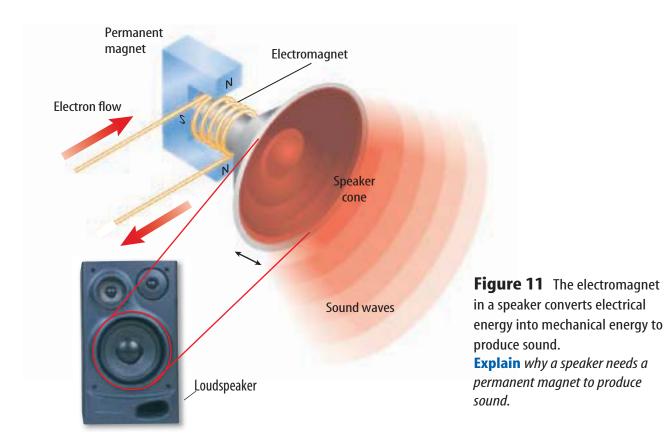
B When many loops of currentcarrying wire are formed into a solenoid, the magnetic field is increased inside the solenoid. The solenoid has a north pole and a south pole.

**Predict** how the field would change if the current reversed direction.





A solenoid wrapped around an iron core forms an electromagnet.



Using Electromagnets to Make Sound How does musical information stored on a CD become sound you can hear? The sound is produced by a loudspeaker that contains an electromagnet connected to a flexible speaker cone that is usually made from paper, plastic, or metal. The electromagnet changes electrical energy to mechanical energy that vibrates the speaker cone to produce sound, as shown on **Figure 11.** 



When you listen to a CD, the CD player produces a voltage that changes according to the musical information on the CD. This varying voltage produces a varying electric current in the electromagnet connected to the speaker cone. Both the amount and the direction of the electric current change, depending on the information on the CD. The varying electric current causes both the strength and the direction of the magnetic field in the electromagnet to change. The electromagnet is surrounded by a permanent, fixed magnet. The changing direction of the magnetic field in the electromagnet causes the electromagnet to be attracted to or repelled by the permanent magnet. This makes the electromagnet move back and forth, causing the speaker cone to vibrate and reproduce the sound that was recorded on the CD.

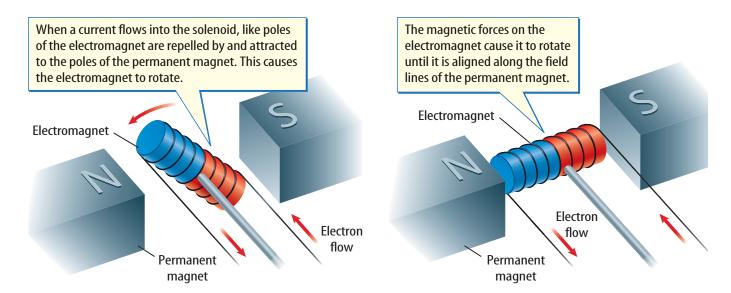
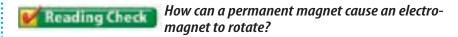


Figure 12 An electromagnet can be made to rotate in a magnetic field.

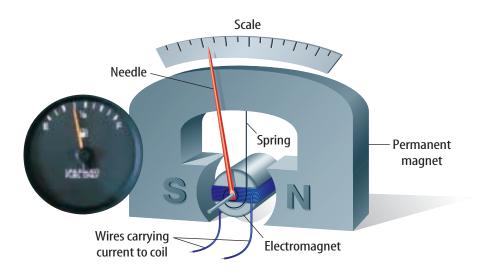
**Making an Electromagnet Rotate** The forces exerted on an electromagnet by another magnet can be used to make the electromagnet rotate. Figure 12 shows an electromagnet suspended between the poles of a permanent magnet. The poles of the electromagnet are repelled by the like poles and attracted by the unlike poles of the permanent magnet. When the electromagnet is in the position shown on the left side of Figure 12, there is a downward force on the left side and an upward force on the right side of the electromagnet forces. These forces cause the electromagnet to rotate as shown.



The electromagnet continues to rotate until its poles are next to the opposite poles of the permanent magnet, as shown on the right side of **Figure 12.** In this position, the forces on the north and south poles of the electromagnet are in opposite directions. The net force on the electromagnet is now zero, and the electromagnet stops rotating.

One way to change the forces that make the electromagnet rotate is to change the current in the electromagnet. Increasing the current increases the strength of the forces that the two magnets exert on each other.

**Galvanometers** You've probably noticed the gauges in the dashboard of a car. One gauge shows the amount of gasoline left in the tank, and another shows the engine temperature. How does a change in the amount of gasoline in a tank or the water temperature in the engine make a needle move in a gauge on the dashboard? These gauges are galvanometers, which are devices that use an electromagnet to measure electric current.



**Figure 13** The rotation of the needle in a galvanometer depends on the amount of current flowing in the electromagnet. The current flowing into the galvanometer in a car's fuel gauge changes as the amount of fuel changes.

**Using Galvanometers** An example of a galvanometer is shown in **Figure 13.** In a galvanometer, the electromagnet is connected to a small spring. The electromagnet rotates until the force exerted by the spring is balanced by the magnetic forces on the electromagnet. Changing the current in the electromagnet causes the needle to rotate to different positions on the scale.

For example, a car's fuel gauge uses a galvanometer. A float in the fuel tank is attached to a sensor that sends a current to the fuel-gauge galvanometer. As the level of the float in the tank changes, the current sent by the sensor changes. The changing current in the galvanometer causes the needle to rotate by different amounts. The gauge is calibrated so that the current sent when the tank is full causes the needle to rotate to the full mark on the scale.

#### **Electric Motors**

On sizzling summer days, do you ever use an electric fan to keep cool? A fan uses an **electric motor**, which is a device that changes electrical energy into mechanical energy. The motor in a fan turns the fan blades, moving air past your skin to make you feel cooler.

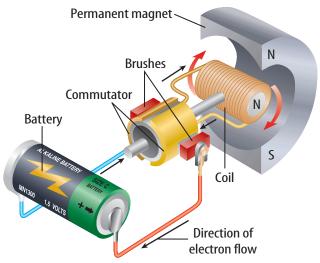
Electric motors are used in all types of industry, agriculture,

and transportation, including airplanes and automobiles. If you were to look carefully, you probably could find electric motors in every room of your home. Almost every appliance in which something moves contains an electric motor. Electric motors are used in devices such as VCRs, CD players, and computers, and

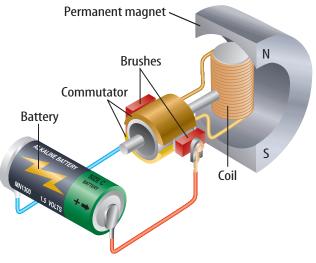
appliances such as those shown in

Figure 14.

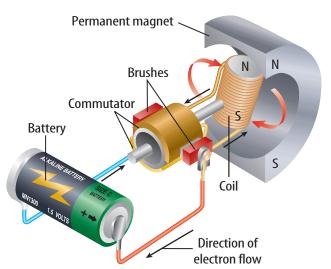
**Figure 14** All the devices shown here contain electric motors. **List** three additional devices that contain electric motors.



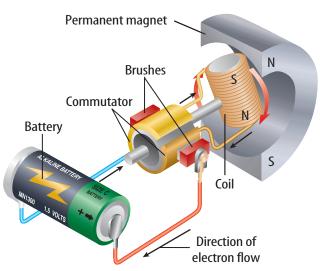
**Step 1** When a current flows in the coil, the magnetic forces between the permanent magnet and the coil cause the coil to rotate.



**Step 2** In this position, the brushes are not in contact with the commutator and no current flows in the coil. The inertia of the coil keeps it rotating.



**Step 3** The commutator reverses the direction of the current in the coil. This flips the north and south poles of the magnetic field around the coil.



**Step 4** The coil rotates until its poles are opposite the poles of the permanent magnet. The commutator reverses the current, and the coil keeps rotating.

**Figure 15** In a simple electric motor, a coil rotates between the poles of a permanent magnet. To keep the coil rotating, the current must change direction twice during each rotation.

**A Simple Electric Motor** A diagram of the simplest type of electric motor is shown in **Figure 15.** The main parts of a simple electric motor include a wire coil, a permanent magnet, and a source of electric current, such as a battery. The battery produces the current that makes the coil an electromagnet. A simple electric motor also includes components called brushes and a commutator. The brushes are conducting pads connected to the battery. The brushes make contact with the commutator, which is a conducting metal ring that is split. Each half of the commutator is connected to one end of the coil so that the commutator rotates with the coil. The brushes and the commutator form a closed electric circuit between the battery and the coil.

**Making the Motor Spin** When current flows in the coil, the forces between the coil and the permanent magnet cause the coil to rotate, as shown in step 1 of **Figure 15.** The coil continues to rotate until it reaches the position shown in step 2. Then, the brushes no longer make contact with the commutator, and no current flows in the coil. As a result, there are no magnetic forces exerted on the coil. However, the inertia of the coil causes it to continue rotating.

In step 3, the coil has rotated so that the brushes again are in contact with the commutator. However, the halves of the commutator that are in contact with the positive and negative battery terminals have switched. This causes the current in the commutator to reverse direction. Now the top of the electromagnet is a north magnetic pole and the bottom is a south pole. These poles are repelled by the nearby like poles of the permanent magnet, and the magnet continues to rotate.

In step 4, the coil rotates until its poles are next to the opposite poles of the permanent magnet. Then the commutator again reverses the direction of the current, enabling the coil to keep rotating. In this way, the coil is kept rotating as long as the battery remains connected to the commutator.



#### **Topic: Electric Motors**

Visit **gpescience.com** for Web links to information about electric motors.

**Activity** Using the information provided at these links, construct a simple electric motor.

# section

#### **Summary**

#### **Electric Current and Magnetic Fields**

- A magnetic field surrounds a moving electric charge.
- The strength of the magnetic field surrounding a current-carrying wire depends on the amount of current.

#### **Electromagnets**

- An electromagnet is a temporary magnet consisting of a current-carrying wire wrapped around an iron core.
- The magnetic properties of an electromagnet can be controlled by changing the current in
- A galvanometer uses an electromagnet to measure electric current.

#### **Electric Motors**

• In a simple electric motor, an electromagnet rotates between the poles of a permanent magnet.

#### **Self Check**

review

- 1. Explain why, if the same current flows in a wire coil and a single wire loop, the magnetic field inside the coil is stronger than the field inside the loop.
- 2. Describe two ways you could change the strength of the magnetic field produced by an electromagnet.
- 3. Predict how the magnetic field produced by an electromagnet would change if the iron core were replaced by an aluminum core.
- **4. Explain** why it is necessary to continually reverse the direction of current flow in the coil of an electric motor.
- 5. Think Critically A bar magnet is repelled when an electromagnet is brought close to it. Describe how the bar magnet would have moved if the current in the electromagnet had been reversed.

#### **Applying Math**

**6. Use a Ratio** The magnetic field strength around a wire at a distance of 1 cm is twice as large as at a distance of 2 cm. How does the field strength at 0.5 cm compare to the field strength at 1 cm?

# **Producing Electric Current**

## **Reading Guide**

#### What You'll Learn

- Define electromagnetic induction.
- Describe how a generator produces an electric current.
- **Distinguish** between alternating current and direct current.
- **Explain** how a transformer can change the voltage of an alternating current.

# Why It's Important

Electromagnetic induction enables power plants to generate the electric current an appliance uses when you plug it into an electric outlet.

#### Review Vocabulary

voltage difference: a measure of the electrical energy provided by charges as they flow in a circuit

#### **New Vocabulary**

- electromagnetic induction
- generator
- turbine
- direct current (DC)
- alternating current (AC)
- transformer

**Figure 16** The coil in a generator is rotated by an outside source of mechanical energy. Here the student supplies the mechanical energy that is converted into electrical energy by the generator.

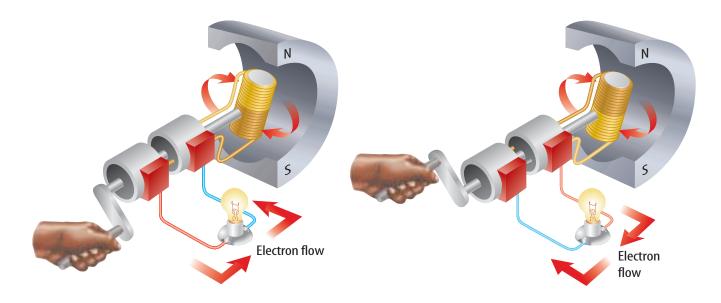


# From Mechanical to Electrical Energy

Working independently in 1831, Michael Faraday in Great Britain and Joseph Henry in the United States both found that moving a loop of wire through a magnetic field causes an electric current to flow in the wire. They also found that moving a magnet through a loop of wire produces a current. In both cases, the mechanical energy associated with the motion of the wire loop or the magnet is converted into electrical energy associated with the current in the wire. The magnet and wire loop must be moving relative to each other for an electric current to be produced. This causes the magnetic field inside the loop to change with time. In addition, if the current in a wire changes with time, the changing magnetic field around the wire can also induce a current in a nearby coil. The generation of a current by a changing magnetic field is electromagnetic induction.

**Generators** Most of the electrical energy you use every day is provided by generators. A generator uses electromagnetic induction to transform mechanical energy into electrical energy. Figure 16 shows one way a generator converts mechanical energy to electrical energy. The mechanical energy is provided by turning the handle on the generator.

An example of a simple generator is shown in **Figure 17.** In this type of generator, a current is produced in the coil as the coil rotates between the poles of a permanent magnet.



**Switching Direction** As the generator's wire coil rotates through the magnetic field of the permanent magnet, current flows through the coil. After the wire coil makes one-half of a revolution, the ends of the coil are moving past the opposite poles of the permanent magnet. This causes the current to change direction. In a generator, as the coil keeps rotating, the current that is produced periodically changes direction. The direction of the current in the coil changes twice with each revolution, as Figure 17 shows. The frequency with which the current changes direction can be controlled by regulating the rotation rate of the generator. In the United States, current is produced by generators that rotate 60 times a second, or 3,600 revolutions per minute.



For each revolution of the coil, how many times does the current change direction?

**The Electromagnetic Force** There is a relationship between electricity and magnetism. A changing magnetic field can cause electric charges to move in a wire. Also, a moving electric charge produces a magnetic field. The atoms of magnetic materials, such as iron, are magnets because of the motion of electric charges in the atoms. As a result, the magnetic field around a permanent magnet is due to electric charges that are in motion.

This connection occurs because the electric force and the magnetic force are two different aspects of the same force. This force is the electromagnetic force and is one of the fundamental forces in nature. An electromagnetic force exists between all objects that have electric charge. Just like the magnetic and the electric force, the electromagnetic force can be attractive or repulsive.

**Figure 17** The current in the coil changes direction each time the ends of the coil move past the poles of the permanent magnet. **Explain** how the frequency of the changing current can be controlled.

**Figure 18** Each of these generators at Hoover Dam can produce over 100,000 kW of electric power. In these generators, a rotating magnet induces an electric current in a stationary wire coil.





Power-Plant Operator Many daily activities require electricity. Powerplant operators control the machinery that generates electricity. Operators must have a high school diploma. College-level courses may be helpful. Research to find employers in your area that hire power plant operators.

**Generating Electricity for Your Home** You probably do not have a generator in your home that supplies the electrical energy you use at home. This electrical energy comes from a power plant with huge generators like the one in **Figure 18.** The coils in these generators have many coils of wire wrapped around huge iron cores. The rotating magnets are connected to a turbine, which is a large wheel that rotates when pushed by water, wind, or steam.

Some power plants first produce thermal energy by burning fossil fuels or using the heat produced by nuclear reactions. This thermal energy is used to heat water and produce steam. Thermal energy is then converted to mechanical energy as the steam pushes the turbine blades. The generator then changes the mechanical energy of the rotating turbine into the electrical energy you use. In some areas, fields of windmills, such as those in Figure 18, can be used to capture the mechanical energy in



wind to turn generators. Other power plants use the mechanical energy in falling water to rotate the turbines. Both generators and electric motors use magnets to produce energy conversions between electrical and mechanical energy. Figure 20 summarizes the differences between electric motors and generators.

**Figure 19** The propeller on each of these windmills is connected to an electric generator. The rotating propeller rotates a coil or a permanent magnet.

# GEOGRAPHIC VISUALIZING MOTORS AND GENERATORS

**Permanent** 

magnet

#### Figure 20

lectric motors power many everyday machines, from CD players to vacuum cleaners. Generators produce the electricity these motors need to run. Both motors and generators use electromagnets, but in different ways. The table below compares motors and generators.

magnet

**Permanent** 

**Electric Motor** 

What does it do?

What makes its electromagnetic

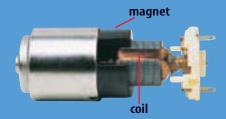
coil rotate?

What is the source of the current that flows in its coil?

How often does the current in the coil change direction?



the coil and the permanent magnet



An outside power source



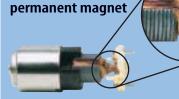
Twice during each rotation of the coil

Generator **Changes movement** into electricity

An outside source of mechanical



**Electromagnetic induction from** moving the coil through the field of the



Twice during each rotation of the coil



#### **Topic: Transformers**

Visit **gpescience.com** for links to information about how transformers transmit electric current.

**Activity** In England, voltage from an outlet is greater than required for U.S. appliances. Using information found at these links, diagram a transformer that would allow a U.S. appliance to operate in England.

**Figure 21** Some devices, such as this radio, can use either direct or alternating current. Electronic components in these devices change alternating current from an electric outlet to direct current.



# **Direct and Alternating Currents**

Modern society relies heavily on electricity. Just how much you rely on electricity becomes obvious during a power outage. Out of habit, you might walk into a room and flip on the light switch. You might try to turn on a radio or television or check the clock to see what time it is. Because power outages sometimes occur, some electrical devices, such as the radio in **Figure 21**, use batteries as a backup source of electrical energy. However, the current produced by a battery is different from the current produced by an electric generator.

A battery produces a direct current. **Direct current** (DC) flows only in one direction through a wire. When you plug your CD player or any other appliance into a wall outlet, you are using alternating current. **Alternating current** (AC) reverses the direction of the current in a regular pattern. In North America, generators produce alternating current at a frequency of 60 cycles per second, or 60 Hz. The electric current produced by a generator changes direction twice during each cycle, or each rotation, of the coil. This means that a 60-Hz alternating current changes direction 120 times each second.

Electronic devices that use batteries as a backup energy source usually require direct current to operate. When the device is plugged into a wall outlet, electronic components inside the device convert the alternating current to direct current and also reduce the voltage of the alternating current.

# **Transmitting Electrical Energy**

The alternating current produced by an electric power plant carries electrical energy that is transmitted along electric transmission lines. However, when electrical energy is transmitted

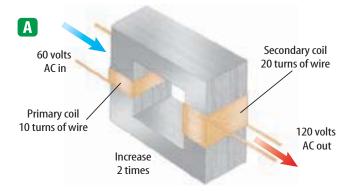
along power lines, some of the electrical energy is converted into heat because of the electrical resistance of the wires. The heat produced in the power lines warms the wires and the surrounding air and can't be used to power electrical devices. Also, the electrical resistance and heat production increase as the wires get longer. As a result, large amounts of heat can be produced when electrical energy is transmitted over long distances.

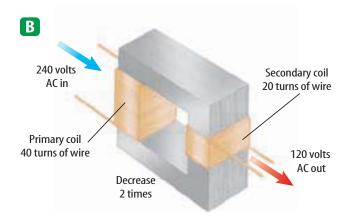
One way to reduce the heat produced in a power line is to transmit the electrical energy at high voltages, typically around 150,000 V. However, electrical energy at such high voltage cannot enter your home safely, nor can it be used in home appliances. Instead, a transformer is used to decrease the voltage.

#### **Transformers**

A **transformer** is a device that increases or decreases the voltage of an alternating current. A transformer is made of a primary coil and a secondary coil. These wire coils are wrapped around the same iron core, as shown in **Figure 22.** As an alternating current passes through the primary coil, the coil's magnetic field magnetizes the iron core. The magnetic field in the primary coil changes direction as the current in the primary coil changes direction. This produces a magnetic field in the iron core that changes direction at the same frequency. The changing magnetic field in the iron core then induces an alternating current with the same frequency in the secondary coil.

The voltage in the primary coil is the input voltage, and the voltage in the secondary coil is the output voltage. The output voltage divided by the input voltage equals the number of turns in the secondary coil divided by the number of turns in the primary coil.





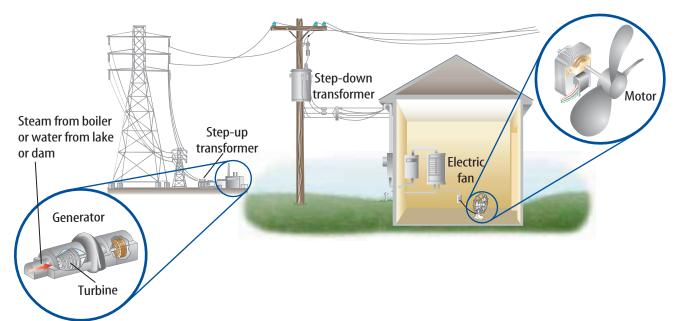


How does a transformer produce an alternating current in the secondary coil?

**Step-Up Transformer** A transformer that increases the voltage so that the output voltage is greater than the input voltage is a step-up transformer. In a step-up transformer, the number of wire turns on the secondary coil is greater than the number of turns on the primary coil. For example, the secondary coil of the step-up transformer in **Figure 22A** has twice as many turns as the primary coil has. The ratio of the output voltage to the input voltage is 2:1, and the output voltage is twice as large as the input voltage. For this transformer, an input voltage of 60 V in the primary coil is increased to 120 V in the secondary coil.

**Step-Down Transformer** A transformer that decreases the voltage so that the output voltage is less than the input voltage is a step-down transformer. In a step-down transformer, the number of wire turns on the secondary coil is less than the number of turns on the primary coil. In **Figure 22B** the secondary coil has half as many turns as the primary coil has, so the ratio of the output voltage to the input voltage is 1:2. The input voltage of 240 V in the primary coil is reduced to a voltage of 120 V in the secondary coil.

Figure 22 Transformers can increase or decrease voltage. A step-up transformer increases voltage. The secondary coil has more turns than the primary coil does. B A step-down transformer decreases voltage. The secondary coil has fewer turns than the primary coil does. Infer whether a transformer could change the voltage of a direct current.



**Figure 23** Many steps are involved in the creation, transportation, and use of the electric current in your home. **Identify** the steps that involve electromagnetic induction.

**Transmitting Alternating Current** Power plants commonly produce alternating current because the voltage can be increased or decreased with transformers. Although step-up transformers and step-down transformers change the voltage at which electrical energy is transmitted, they do not change the amount of electrical energy transmitted. **Figure 23** shows how step-up and step-down transformers are used in transmitting electrical energy from power plants to your home.

# section (1) review

#### Summary

#### From Mechanical to Electrical Energy

- An electric current is produced by moving a wire loop through a magnetic field or a magnet through a wire loop.
- A generator can produce an electric current by rotating a wire coil in a magnetic field.

#### **Direct and Alternating Currents**

 A direct current flows in one direction. An alternating current changes direction in a regular pattern.

#### **Transformers**

- A transformer changes the voltage of an alternating current. The voltage can be increased or decreased.
- The changing magnetic field in the primary coil of a transformer induces an alternating current in the secondary coil.

#### **Self Check**

- **1. Describe** the energy conversions that occur when water falls on a paddle wheel connected to a generator that is connected to electric lights.
- **2. Compare and contrast** a generator with an electric motor.
- **3. Explain** why the output voltage from a transformer is zero if a direct current flows through the primary coil.
- **4. Explain** why electric current produced by power plants is transmitted as alternating current.
- **5. Think Critically** A magnet is pushed into the center of a wire loop and then stops. What is the current in the wire loop after the magnet stops moving? Explain.

#### **Applying Math**

**6. Use a Ratio** A transformer has 1,000 turns of wire in the primary coil and 50 turns in the secondary coil. If the input voltage is 2,400 V, what is the output voltage?



# **El®ctricity and Magnetism**

Huge generators in power plants produce electricity by moving magnets past coils of wire. How does this produce an electric current?

## Real-World Problem

How can a magnet and a wire coil be used to produce an electric current?

#### Goals

- **Observe** how a magnet and a wire coil can produce an electric current in a wire.
- **Compare** the currents created by moving the magnet and the wire coil in different ways.

#### **Materials**

cardboard tube scissors

bar magnet galvanometer or ammeter insulated wire

#### Safety Precautions 🗪 🌃 🛣

## Procedure

- 1. Complete the safety form.
- 2. Wrap the wire around the cardboard tube to make a coil of about 20 turns. Remove the tube from the coil.
- Use the scissors to cut and remove 2 cm of insulation from each end of the wire.
- **4.** Connect the ends of the wire to a galvanometer or ammeter. Record the reading on your meter.
- 5. Insert one end of the magnet into the coil and then pull it out. Record the current. Move the magnet at different speeds inside the coil and record the current.



- **6.** Watch the meter and move the bar magnet in different ways around the outside of the coil. Record your observations.
- **7.** Repeat steps 5 and 6, keeping the magnet stationary and moving the wire coil.

# Conclude and Apply

- 1. How was the largest current generated?
- **2.** Does the current generated always flow in the same direction? How do you know?
- Predict what would happen if you used a coil made with fewer turns of wire.
- 4. Infer whether a current would have been generated if the cardboard tube had been left in the coil. Why or why not? Try it.

# Communicating Your Data

Compare the currents generated by different members of the class. What was the value of the largest current that was generated? How was this current generated?



# **Design Your Own**

# CONTROLLING ELECTROMAGNETS

#### Goals

- **Measure** relative strengths of electromagnets.
- **Determine** which factors affect the strength of an electromagnet.

#### **Possible Materials**

22-gauge insulated wire 16-penny iron nail aluminum rod or nail 6-V DC power supply three 1.5-V D cells steel paper clips magnetic compass duct tape (to hold D cells together)

### **Safety Precautions**



WARNING: Do not leave the electromagnet connected for long periods of time because the battery will run down. Magnets will get hot with only a few turns of wire. Use caution in handling them when current is flowing through the coil. Do not apply voltages higher than 6 V to the electromagnets.

#### 🤘 Real-World Problem

You use electromagnets every day when you use stereo speakers, power door locks, and many other devices. To make these devices work properly, the strength of the magnetic field surrounding an electromagnet must be controlled. How can the magnetic field produced by an electromagnet be made stronger or weaker? Think about the components that form an electromagnet. Make a hypothesis about how changing these components would affect the strength of the electromagnet's magnetic field.

# Form a Hypothesis

As a group, write down the components of an electromagnet that might affect the strength of its magnetic field.

# Test Your Hypothesis

#### Make a Plan

- **1.** Write your hypothesis about the best way to control the magnetic field strength of an electromagnet.
- **2. Decide** how you will assemble and test the electromagnets. Which features will you change to determine the effect on the strength of the magnetic fields? How many changes will you need to try? How many electromagnets do you need to build?
- 3. **Decide** how you are going to test the strength of your electromagnets. Several ways are possible with the materials listed. Which



# Using Scientific Methods

**4.** Write your plan of investigation. Make sure your plan tests only one variable at a time.

#### **Follow Your Plan**

- **1.** Before you begin to build and test the electromagnets, make sure your teacher approves of your plan.
- 2. Carry out your planned investigation.
- 3. Record your results.

# Analyze Your Data

- **1. Make a table** showing how the strength of your electromagnet depends on changes you made in its construction or operation.
- **2. Examine** the trends shown by your data. Are there any data points that seem out of line? How can you account for them?

Testing Electromagnets				
Trial	Electromagnet Construction Features	Strength of Electromagnet		
	Do not write in this book.			

# Conclude and Apply

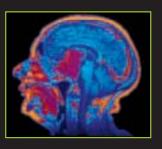
- **1. Describe** how the electromagnet's magnetic-field strength depended on its construction or operation.
- 2. Identify the features of the electromagnet's construction that had the greatest effect on its magnetic-field strength. Which do you think would be easiest to control?
- **3. Explain** how you could use your electromagnet to make a switch. Would it work with both AC and DC?
- **4. Evaluate** whether or not your results support your hypothesis. Explain.



**Compare** your group's result with those of other groups. Did any other group use a different method to test the strength of the magnet? Did you get the same results?

# SCIENCE AND SCIENCE CAN CHANGE THE COURSE OF HISTORY!

# Body



# Art

the patient can see it. Pointing to a colorful image of the patient's brain, she reassures the worried patient. "This MRI shows exactly where your tumor is. We can remove it with little danger to you."

#### **MRI for the Soft Stuff**

MRI stands for "magnetic resonance imaging." It's a way to take 3-D pictures of the inside of your body. Before the 1980s, doctors could x-ray solid tissue such as bones, but had no way to see soft tissue such as the brain. Well, they had one way—surgery, which sometimes caused injury and infection, risking a patient's health.

MRI uses a strong magnet and radio waves. Tissues in your body contain water molecules that are made of oxygen and hydrogen atoms.

This patient is about to be placed in an MRI machine.



The nucleus of a hydrogen atom is a proton, which behaves like a tiny magnet. A strong magnetic field inside the MRI tube makes these proton magnets line up in the direction of the field. Radio waves are then applied to the body. The protons absorb some of the radio-wave energy, and flip their direction.

When the radio waves are turned off, the protons realign themselves with the magnetic field and emit the energy they absorbed. Different tissues in the body absorb and emit different amounts of energy. The emitted energy is detected, and a computer uses this information to form images of the body.

# Your brain is getting bigger!

MRI has turned into an important research tool. For example, researchers using MRI have found that the brain grows rapidly through ado-

lescence. Before this research, people thought that the brain stopped growing in childhood. MRI has proven that adolescents are getting bigger brains all the time.

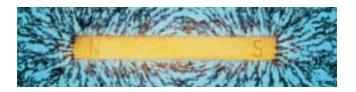
**Interview** As an oral history project, interview a retired physician or surgeon. Ask him or her to discuss with you how tools such as MRI changed during his or her career. Make a list of the tools and how they have helped improve medicine.

TIME
For more information, visit gpescience.com

# **Reviewing Main Ideas**

#### Section 1 Magnetism

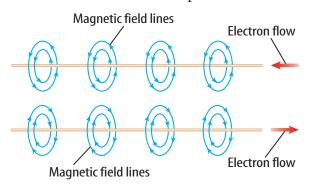
- 1. A magnetic field surrounds a magnet and exerts a magnetic force.
- 2. All magnets have two poles: a south pole and a north pole.



- **3.** Opposite poles of magnets attract; like poles repel.
- **4.** Groups of atoms with aligned magnetic poles are called magnetic domains.

#### **Section 2 Electricity and Magnetism**

- **1.** An electric current flowing through a wire produces a magnetic field.
- 2. An electric current passing through a coil of wire can produce a magnetic field inside the coil. The coil becomes an electromagnet. One end of the coil is the north pole, and the other end is the south pole.

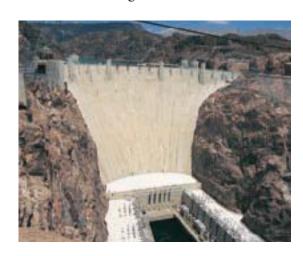


**3.** The magnetic field around an electromagnet depends on the current and the number of coils.

**4.** An electric motor contains a rotating electromagnet that converts electrical energy to mechanical energy.

## **Section 3 Producing Electric Current**

1. By moving a magnet near a wire, you can create an electric current in the wire. This is called electromagnetic induction.



- **2.** A generator produces electric current by rotating a coil of wire in a magnetic field. Generators at the base of this dam convert the kinetic energy in falling water into electrical energy.
- **3.** Direct current flows in one direction through a wire; alternating current reverses the direction of current flow in a regular pattern.
- **4.** The number of turns of wire in the primary and secondary coils of a transformer determines whether it increases or decreases voltage.

FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review magnets and magnetism.

### **Using Vocabulary**

alternating current (AC)
p. 442
direct current (DC) p. 442
electric motor p. 435
electromagnet p. 432
electromagnetic induction
p. 438
galvanometer p. 434

generator p. 438
magnetic domains p. 429
magnetic field p. 425
magnetic pole p. 425
magnetism p. 424
solenoid p. 432
transformer p. 443
turbine p. 440

Complete each statement with the correct vocabulary word or phrase.

- **1.** A(n) \_\_\_\_\_ can be used to change the voltage of an alternating current.
- **2.** A(n) \_\_\_\_\_\_ is the region where the magnetic field of a magnet is strongest.
- **3.** \_\_\_\_\_ does not change direction.
- **4.** The properties and interactions of magnets are called \_\_\_\_\_.
- **5.** A(n) \_\_\_\_\_ can rotate in a magnetic field when a current passes through it.
- **6.** The magnetic poles of atoms are aligned in a(n) \_\_\_\_\_.
- **7.** A device that uses an electromagnet to measure electric current is a(n) \_\_\_\_\_\_.

#### **Checking Concepts**

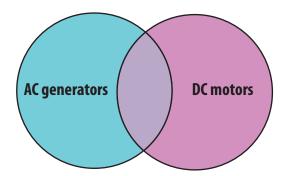
Choose the word or phrase that best answers the question.

- **8.** Where is the magnetic force exerted by a magnet strongest?
  - A) both poles
- **c)** north pole
- **B)** south pole
- **D)** center
- **9.** Which change occurs in an electric motor?
  - A) electrical energy to mechanical energy
  - **B)** thermal energy to wind energy
  - c) mechanical energy to electrical energy
  - **D)** wind energy to electrical energy

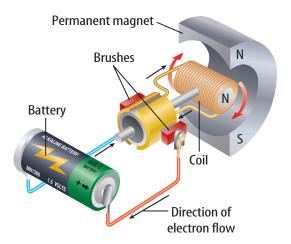
- **10.** What happens to the magnetic force as the distance between two magnetic poles decreases?
  - **A)** remains constant
- **C)** increases
- **B)** decreases
- **D)** becomes zero
- **11.** Which of the following best describes what type of magnetic poles the domains at the north pole of a bar magnet have?
  - A) north magnetic poles only
  - **B)** south magnetic poles only
  - c) no magnetic poles
  - **D)** north and south magnetic poles
- **12.** Which of the following would not change the strength of an electromagnet?
  - A) increasing the amount of current
  - **B)** changing the current's direction
  - c) inserting an iron core inside the coil
  - **D)** increasing the number of loops
- **13.** Which of the following is NOT part of a generator?
  - **A)** turbine
- **c)** electromagnet
- **B)** battery
- **D)** permanent magnet
- **14.** Which of the following describes the direction of the electric current in AC?
  - **A)** is constant
- c) changes regularly
- **B)** is direct
- **D)** changes irregularly

#### **Interpreting Graphics**

**15.** Copy and complete the Venn diagram below. Include the functions, part names, and power sources for these devices.

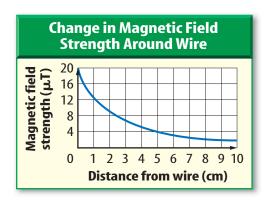


#### Use the diagram below to answer questions 16 and 17.



- **16. Describe** Using the diagram, describe the function of the permanent magnet, the electromagnet, and the current source in a simple electric motor.
- 17. Describe the sequence of steps that occur in an electric motor that forces the coil to spin. Include the role of the commutator in your description.

Use the graph below to answer questions 18-20.



- **18. Explain** How much larger is the magnetic field strength 1 cm from the wire compared to 5 cm from the wire?
- **19. Explain** Does the magnetic field strength decrease more rapidly with distance closer to the wire or farther from the wire? Explain.
- **20.** Solve Using the graph, estimate the magnetic field strength 11 cm from the wire.

#### **Thinking Critically**

- **21. Infer** how you could you use a horseshoe magnet to find the north direction.
- **22.** Explain In Europe, generators produce alternating current at a frequency of 50 Hz. Would the electric appliances you use in North America work if you plugged them into an outlet in Europe? Why or why not?
- **23. Predict** Two generators are identical except for the loops of wire that rotate through their magnetic fields. One has twice as many turns of wire as the other one does. Which generator will produce the most electric current? Why?
- **24.** Explain why a bar magnet will attract an iron nail to either its north pole or its south pole, but it will attract another magnet to only one of its poles.
- **25.** Compare and contrast electromagnetic induction and the formation of electromagnets.

#### **Applying Math**

- **26. Calculate** A step-down transformer reduces a 2,400-V current to 120 V. If the primary coil has 500 turns of wire, how many turns of wire are there on the secondary coil?
- **27.** Use a Ratio To produce a spark, a spark plug requires a current of about 12,000 V. A car's engine uses a type of transformer called an induction coil to change the input voltage from 12 V to 12,000 V. In the induction coil, what is the ratio of the number of wire turns on the primary coil to the number of turns on the secondary coil?

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### **Multiple Choice**

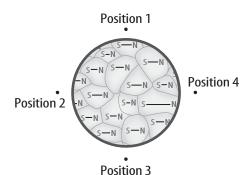
A transformer has 50 turns of wire on the primary coil and 10 turns of wire on the secondary coil. The effect of changing the input voltage is summarized in the table below.

#### Use the table below to answer questions 1 and 2.

Voltage and Current in a Transformer						
Trial	Input Voltage (V)	Primary Coil Current (A)	Output Voltage (V)	Secondary Coil Current (A)		
1	5	0.1	1	0.5		
2	10	0.2	2	1.0		
3	20	0.2	4	1.0		
4	50	0.5	10	2.5		

- **1.** What is the ratio of the input voltage to the output voltage for this transformer?
  - **A.** 1:2.5
  - **B.** 4:1
  - **C.** 5:1
  - **D.** 1:5
- **2.** What is the ratio of the secondary-coil current to the primary-coil current?
  - **A.** the ratio of the secondary-coil wire turns to the primary-coil wire turns
  - **B.** the ratio of the output voltage to the input voltage
  - **c.** the ratio of the primary-coil wire turns to the secondary-coil wire turns
  - **D.** It always equals one.

#### Use the figure below to answer question 3.



- **3.** A steel paper clip is sitting on a desk. The figure above shows the magnetic domains in a section of the paper clip after the north pole of a magnet has been moved close to it. According to the diagram, the magnet's north pole is at which position?
  - **A.** position 1
  - **B.** position 2
  - **c.** position 3
  - **D.** position 4
- **4.** A hydroelectric power plant uses water to spin a turbine attached to a generator. The generator produces 30,000 kW of electric power. If the turbine and generator are a combined 75 percent efficient, how much power does the falling water supply to the turbine?
  - **A.** 50,000 kW
  - **B.** 40,000 kW
  - **c.** 22,500 kW
  - **D.** 20,000 kW

#### **Gridded Response**

Use the figure below to answer questions 5 and 6.



- **5.** A step-down transformer is plugged into a 120-V electric outlet and a lightbulb is connected to the output coil. The transformer has 20 turns on the primary coil and 2 turns on the secondary coil. What is the voltage, in volts, at the output coil?
- **6.** If the lightbulb has a resistance of 8  $\Omega$ , what is the current, in amperes, in the lightbulb?

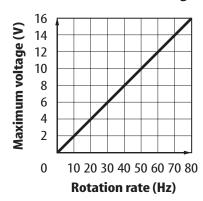
#### **Short Response**

- **7.** A bicycle has a small electric generator that is used to light a headlight. The generator is made to spin by rubbing against a wheel. Will the bicycle coast farther on a level surface if the light is turned on or turned off?
- **8.** A student connects a battery to a step-up transformer to boost the voltage. Explain why a small electric motor does not spin when it is connected to the secondary coil of the transformer.

#### **Extended Response**

Use the figure below to answer question 9.

#### **Effect of Rotation** on Generator Voltage



- **9.** The graphic above shows how the voltage produced by a generator depends on the rotation rate of the coil. Explain whether this generator could produce household AC current that is 120 V at 60 Hz.
- **10.** Compare and contrast the behavior and properties of positive and negative electric charges with north and south magnetic poles.

#### Test-Taking Tip

**Read All the Information** If a question includes a text passage and a graphic, carefully read the information in the text passage and the graphic before answering the question.

**Question 1** Review the information in the text above the table and the information in the table.

# chapter



#### BIG (Idea

Electromagnetic waves can transfer energy through matter and space.

# 15.1 What are electromagnetic waves?

MAIN (Idea Electromagnetic waves are transverse waves that can be produced by vibrating electric charges.

# 15.2 The Electromagnetic Spectrum

MAIN (Idea Each type of electromagnetic wave has a certain range of frequencies and wavelengths.

#### 15.3 Radio Communication

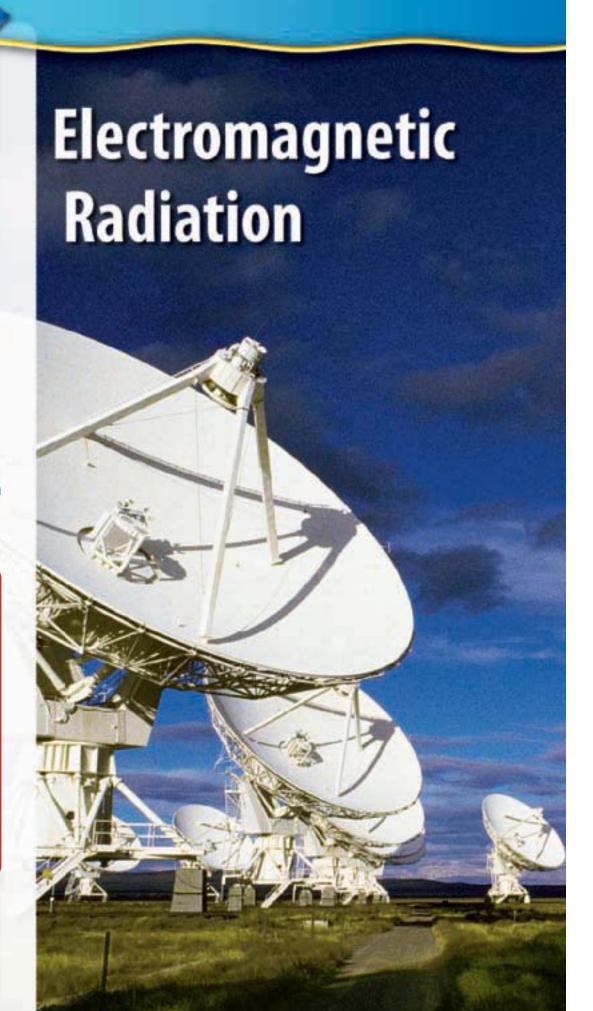
MAIN (Idea Signals and information can be transmitted using radio waves.

#### How's the reception?

These giant 25-m dishes aren't picking up TV signals. Instead, they are part of a group of 27 antennas that detect radio waves coming from distant stars and galaxies. Radio waves, like microwaves and light waves, are electromagnetic waves. All objects, including you, emit electromagnetic waves.

#### **Science Journal**

List six objects around you that emit light or feel warm.



# **Start-Up Activities**



# Can electromagnetic waves change materials?

You often hear about the danger of the Sun's ultraviolet rays, which can damage the cells of your skin. When the exposure isn't too great, your cells can repair themselves, but too much at one time can cause a painful sunburn. Repeated overexposure to the Sun over many years can damage cells and cause skin cancer. In the lab below, observe how energy carried by ultraviolet waves can cause changes in other materials.

- 1. Complete the safety form.
- 2. Cut a sheet of red construction paper in half.
- 3. Place one piece outside in direct sunlight. Place the other in a shaded location.
- 4. Keep the construction paper in full sunlight for at least 45 min. If possible, allow it to stay there for 3 h or more before taking it down. Be sure the other piece remains in the shade.
- 5. Think Critically In your Science Journal, describe any differences you notice in the two pieces of construction paper. Comment on your results.



**Electromagnetic Waves**Make the following Foldable to help you understand

electromagnetic waves.

Fold a sheet of paper vertically in half from top to bottom.



**STEP 2 Fold** in half from side to side with the fold at the top.



STEP 3 Unfold the paper once. Cut only the fold of the top flap to make two tabs.



STEP 3 Write on the front tabs as shown.



How do electromagnetic waves transfer energy to matter?

**Identify Questions** As you read the chapter, write answers to the questions on the back of the appropriate tabs.



Preview this chapter's content and activities at qpescience.com

Bob Burch/Index Stock Imager

# **What are** electromagnetic waves?

# **Reading Guide**

# What You'll Learn

- Describe how electric and magnetic fields form electromagnetic
- **Explain** how vibrating charges produce electromagnetic waves.
- Describe properties of electromagnetic waves.

## Why It's Important

You, and all the objects and materials around you, are radiating electromagnetic waves.

#### Review Vocabulary

**hertz:** the SI unit of frequency, abbreviated Hz; 1 Hz equals one vibration per second

#### New Vocabulary

- electromagnetic wave
- radiant energy
- photon

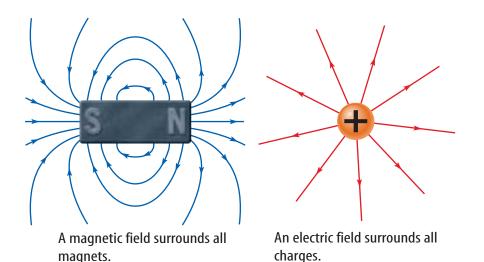
Figure 1 Water waves and sound waves require matter to move through. Energy is transferred from one particle to the next as the wave travels through the matter.

# **Waves in Space**

Stay calm. Do not panic. As you are reading this sentence, no matter where you are, you are surrounded by electromagnetic waves. Even though you can't feel them, some of these waves are traveling right through your body. They enable you to see. They make your skin feel warm. You use electromagnetic waves when you watch television, talk on a cordless phone, or prepare popcorn in a microwave oven.

Sound and Water Waves Waves are produced by something that vibrates, and they transmit energy from one place to another. Look at the sound wave and the water wave in **Figure 1.** Both waves are moving through matter. The sound wave is moving through air and the water wave through water. These waves travel because energy is transferred from particle to particle. Without matter to transfer the energy, waves cannot move.

**Electromagnetic Waves** However, electromagnetic waves do not require matter to transfer energy. **Electromagnetic waves** are made by vibrating electric charges and can travel through space where matter is not present. Instead of transferring energy from particle to particle, electromagnetic waves travel by transferring energy between vibrating electric and magnetic fields.



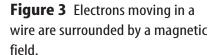
**Figure 2** Fields enable magnets and charges to exert forces at a distance. These fields extend throughout space. **Explain** how you could detect a magnetic field.

# **Electric and Magnetic Fields**

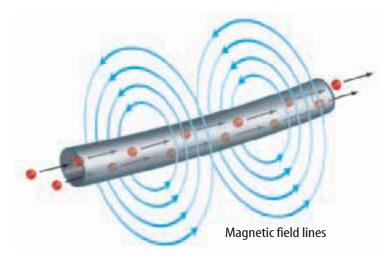
When you bring a magnet near a metal paper clip, the paper clip moves toward the magnet and sticks to it. The paper clip moves because the magnet exerts a force on it. The magnet exerts this force without having to touch the paper clip because all magnets are surrounded by a magnetic field, as shown in **Figure 2.** Magnetic fields exist around magnets even if the space around the magnets contains no matter.

Just as magnets are surrounded by magnetic fields, electric charges are surrounded by electric fields, also shown in **Figure 2**. An electric field enables charges to exert forces on each other even when they are far apart. Just as a magnetic field around a magnet can exist in empty space, an electric field exists around an electric charge even if the space around it contains no matter.

**Magnetic Fields and Moving Charges** Electric charges also can be surrounded by magnetic fields. It is the motion of electrons that generates the magnetic field. An electric current, the net flow of electrons in one direction, is always surrounded by a magnetic field. In fact, any moving electric charge is surrounded by a magnetic field, as well as an electric field. For example, an electric current flowing through a wire is surrounded by a magnetic field, as illustrated in **Figure 3.** 



**Describe** how you would confirm that a magnetic field exists around a current-carrying wire.





#### **Investigating Electromagnetic Waves**

#### 



- 1. Complete the safety form.
- 2. Point your television remote control in different directions and observe whether it will still control the television.
- **3.** Place various materials in front of the infrared receiver on the television and observe whether the remote still controls the television. Some materials you might try are glass, a book, your hand, paper, and a metal pan.

#### **Analysis**

- **1.** Was it necessary for the remote control to be pointing exactly toward the receiver to control the television? Explain.
- 2. Did the remote control work when the various materials were placed between it and the receiver? Explain.

**Figure 4** A vibrating electric charge creates an electromagnetic wave that travels outward in all directions from the charge. The wave in only one direction is shown here.

**Determine** whether an electromagnetic wave is a transverse wave or a compressional wave.

**Changing Electric and Magnetic Fields** A changing magnetic field creates a changing electric field. For example, in a transformer, changing electric current in the primary coil produces a changing magnetic field. This changing magnetic field then creates a changing electric field in the secondary coil that produces current in the coil. The reverse is also true: a changing electric field creates a changing magnetic field.

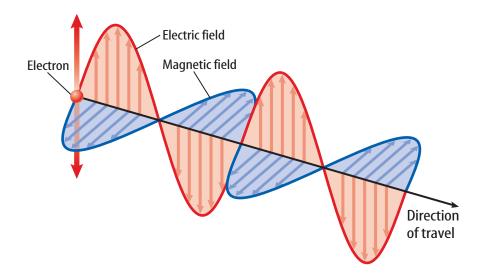
## **Making Electromagnetic Waves**

Waves such as sound waves are produced when something vibrates. Electromagnetic waves also are produced when something vibrates—an electric charge that moves back and forth.

Reading Check What produces an electromagnetic wave?

When an electric charge vibrates, the electric field around it changes. Because the electric charge is in motion, it also has a magnetic field around it. This magnetic field also changes as the charge vibrates. As a result, the vibrating electric charge is surrounded by changing electric and magnetic fields.

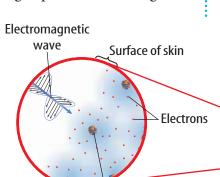
How do the vibrating electric and magnetic fields around the charge become a wave that travels through space? The changing electric field around the charge creates a changing magnetic field. This changing magnetic field then creates a changing electric field. This process continues, with the magnetic and electric fields continually creating each other. These vibrating electric and magnetic fields are perpendicular to each other and travel outward from the moving charge, as shown in Figure 4. Because the electric and magnetic fields vibrate at right angles to the direction the wave travels, an electromagnetic wave is a transverse wave.



# **Properties of Electromagnetic Waves**

All matter contains charged particles that are always in motion. As a result, all objects emit electromagnetic waves. The wavelengths of the emitted waves become shorter as the temperature of the material increases. As an electromagnetic wave moves, its electric and magnetic fields encounter objects. These vibrating fields can exert forces on charged particles and magnetic

materials, causing them to move. For example, electromagnetic waves from the Sun cause electrons in your skin to vibrate and gain energy, as shown in **Figure 5.** The energy transferred by an electromagnetic wave is radiant energy. Radiant energy makes a fire feel warm and enables you to see.



**Figure 5** As an electromagnetic wave strikes your skin, electrons in your skin gain energy from the vibrating electric and magnetic fields.



#### **Applying Math**

#### **Using Scientific Notation**

Nucleus

THE SPEED OF LIGHT IN WATER The speed of light in water is 226,000 km/s. Write this number in scientific notation.

#### **IDENTIFY** known values and the unknown value

#### Identify the known values:

The speed of light in water is 226,000 km/s.

#### Identify the unknown value:

the number 226,000 written in scientific notation

#### **SOLVE** the problem

A number written in scientific notation has the form  $M \times 10^N$ . N is the number of places the decimal point in the number has to be moved so that the number M that results has only one digit to the left of the decimal point.

Write the number in scientific notation:  $226,000. \times 10^{N}$ Move the decimal point so there is only one digit to its left:  $2.26000 \times 10^{N}$ The decimal point was moved 5 places, so N equals 5:  $2.26000 \times 10^{5}$ Delete remaining zeroes at the end of the number.  $2.26 \times 10^{5}$ 

#### CHECK your answer

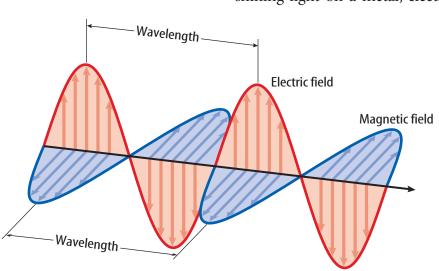
Add zeroes to the end of the number and move the decimal point in the opposite direction five places. The result should be the original number.

#### **Practice Problems**

Write the following numbers in scientific notation: 433; 812,000,000; 73,000,000,000; 84,500. For more practice problems go to page 879, and visit Math Practice at gpescience.com.

Table 1 Speed of Visible Light		
Material	Speed (km/s)	
Vacuum	300,000	
Air	slightly less than 300,000	
Water	226,000	
Glass	200,000	
Diamond	124,000	

**Figure 6** The wavelength of an electromagnetic wave is the distance between the crests of the vibrating electric field or magnetic field.



**Wave Speed** All electromagnetic waves travel at 300,000 km/s in the vacuum of space. Because light is an electromagnetic wave, the speed of electromagnetic waves in space is usually called the speed of light. The speed of light is nature's speed limit—nothing travels faster than the speed of light. In matter, the speed of electromagnetic waves depends on the material they travel through. Electromagnetic waves usually travel most slowly in solids and fastest in gases. **Table 1** lists the speed of visible light in various materials.

Reading Check What is the speed of light?

**Wavelength and Frequency** Like all waves, electromagnetic waves can be described by their wavelengths and frequencies. The wavelength of an electromagnetic wave is the distance from one crest to another, as shown in **Figure 6.** 

The frequency of any wave is the number of wavelengths that pass a point in 1 s. The frequency of an electromagnetic wave also equals the frequency of the vibrating charge that produces the wave. This frequency is the number of vibrations, or back-andforth movements, of the charge in one second. The frequency and wavelength of an electromagnetic wave are related. As the frequency increases, the wavelength becomes smaller.

# **Waves and Particles**

The difference between a wave and a particle might seem obvious—a wave is a disturbance that carries energy, and a particle is a piece of matter. However, in reality, the difference is not so clear.

Waves as Particles In 1887, Heinrich Hertz found that by shining light on a metal, electrons were ejected from the metal.

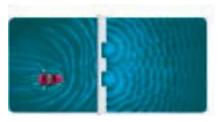
> Hertz found that whether or not electrons were ejected depended on the frequency of the light and not on the amplitude. Because the energy carried by a wave depends on its amplitude and not its frequency, this result was mysterious. Years later, Albert Einstein provided an explanation: electromagnetic waves can behave as a particle, called a **photon**, whose energy depends on the frequency of the waves.



Particles of paint sprayed through two slits coat only the area behind the slits.



Electrons fired at two closely spaced openings form a wavelike interference pattern.



Water waves produce an interference pattern after passing through two openings.

Particles as Waves Because electromagnetic waves could behave as a particle, other scientists wondered whether matter could behave as a wave. If a beam of electrons were sprayed at two tiny slits, you might expect that the electrons would strike only the area behind the slits, like the spray paint in **Figure 7.** Instead, it was found that the electrons formed an interference pattern. This type of pattern is produced by waves when they pass through two slits and interfere with each other, as the water waves do in **Figure 7.** This experiment showed that electrons can behave like waves. It is now known that all particles, not only electrons, can behave like waves.

**Figure 7** When electrons are sent through two narrow slits, they behave as a wave.

## section

#### **Summary**

#### **Making Electromagnetic Waves**

- Moving electric charges are surrounded by an electric field and a magnetic field.
- A vibrating electric charge produces an electromagnetic wave.
- An electromagnetic wave consists of vibrating electric and magnetic fields that are perpendicular to each other and travel outward from the vibrating electric charge.

#### **Properties of Electromagnetic Waves**

- Electromagnetic waves carry radiant energy.
- In empty space, electromagnetic waves travel at 300,000 km/s, the speed of light.
- Electromagnetic waves travel more slowly in matter, with a speed that depends on the material.

#### **Waves and Particles**

- Electromagnetic waves can behave as particles that are called photons.
- In some circumstances, particles, such as electrons, can behave as waves.

### **Self Check**

гечіеш

- **1. Explain** why an electromagnetic wave is a transverse wave and not a compressional wave.
- **2. Compare** the frequency of an electromagnetic wave with the frequency of the vibrating charge that produces the wave.
- 3. **Describe** how electromagnetic waves transfer radiant energy to matter.
- **4. Explain** how an electromagnetic wave can travel through space that contains no matter.
- **5. Think Critically** Suppose a moving electric charge were surrounded only by an electric field. Infer whether or not a vibrating electric charge would produce an electromagnetic wave.

#### **Applying Math**

- **6. Calculate Time** How many minutes does it take an electromagnetic wave to travel 150,000,000 km?
- **7. Use Scientific Notation** Calculate the distance an electromagnetic wave in space would travel in one day. Express your answer in scientific notation.

# The Electromagnetic Spectrum

# **Reading Guide**

#### What You'll Learn

- **Describe** the waves in the different regions of the electromagnetic spectrum.
- **Compare** the properties of different electromagnetic waves.
- Identify uses for different types of electromagnetic waves.

# Why It's Important

Waves in different regions of the electromagnetic spectrum are used every day in many ways.

#### Review Vocabulary

spectrum: a continuous sequence arranged by a particular property

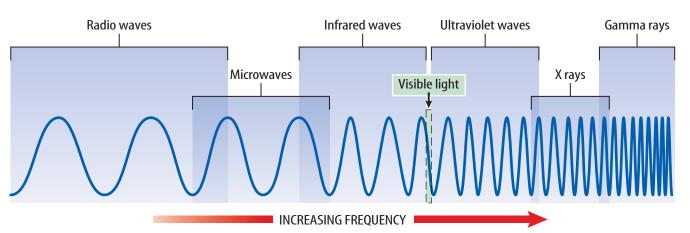
#### **New Vocabulary**

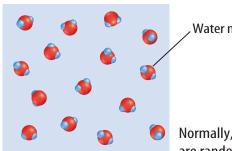
- visible light
- radio wave
- microwave
- infrared wave
- ultraviolet wave
- X rav
- gamma ray

# A Range of Frequencies

Electromagnetic waves can have a wide variety of frequencies. They might vibrate once each second or trillions of times each second. The entire range of electromagnetic wave frequencies is known as the electromagnetic spectrum, shown in **Figure 8.** Various portions of the electromagnetic spectrum interact with matter differently. As a result, they are given different names. The electromagnetic waves that humans can detect with their eyes, called visible light, are a small portion of the entire electromagnetic spectrum. However, various devices have been developed to detect the other frequencies. For example, the antenna of your radio detects radio waves.

Figure 8 Electromagnetic waves are described by different names, depending on their frequencies and wavelengths.





Water molecules

Normally, water molecules are randomly arranged.

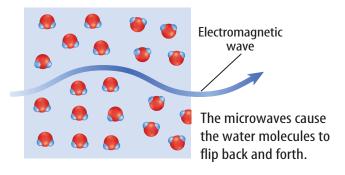


Figure 9 Microwave ovens use electromagnetic waves to heat food.

#### **Radio Waves**

Stop and look around you. Even though you can't see them, radio waves are moving everywhere you look. Some radio waves carry an audio signal from a radio station to a radio. However, even though these radio waves carry information that a radio uses to create sound, you can't hear radio waves. You hear a sound wave when the compressions and rarefactions the sound wave produces reach your ears. A radio wave does not produce compressions and rarefactions as it travels through air.

Microwaves Radio waves are low-frequency electromagnetic waves with wavelengths longer than about 1 mm. Radio waves with wavelengths of less than 30 cm are called microwaves. Microwaves with wavelengths of about 20 cm to 1 cm are widely used for communication, such as for cellular telephones and satellite signals. You are probably most familiar with microwaves because of their use in microwave ovens.



What is the difference between a microwave and a radio wave?

Microwave ovens heat food when microwaves interact with water molecules in food, as shown in **Figure 9.** Each water molecule is positively charged on one side and negatively charged on the other side. The vibrating electric field inside a microwave oven causes water molecules in food to rotate back and forth billions of times each second. This rotation causes a type of friction between water molecules that generates thermal energy. It is the thermal energy produced by the interactions between the water molecules that causes your food to cook.

**Radar** Another use for radio waves is to find the position and movement of objects by a method called radar. Radar stands for RAdio Detecting And Ranging. With radar, radio waves are transmitted toward an object. By measuring the time required for the waves to bounce off the object and return to a receiving antenna, the location of the object can be found. Law-enforcement officers use radar to measure how fast a vehicle is moving. Radar also is used for tracking the movement of aircraft, watercraft, and spacecraft.



#### **Heating with Microwaves**

#### **Procedure**

- 1. Complete the safety form.
- 2. Obtain two small beakers or baby-food jars. Place 50 mL of dry sand in each. To one of the jars, add 20 mL of roomtemperature water and stir well.
- **3.** Record the temperature of the sand in each jar.
- **4.** Together, **microwave** both iars of sand for 10 s and immediately record the temperature again.

#### **Analysis**

- **1.** Compare the initial and final temperatures of the wet and dry sand.
- 2. Infer why there was a difference.



Figure 10 Magnetic resonance imaging technology uses radio waves as an alternative to X-ray imaging.

**Figure 11** Infrared images and visible light images can provide different types of information.

This visible light image of the region around San Francisco Bay in California was taken from an aircraft at an altitude of 20,000 m.

Magnetic Resonance Imaging (MRI) In the early 1980s, medical researchers developed a technique called magnetic resonance imaging, which uses radio waves to help diagnose illness. The patient lies inside a large cylinder, such as the one shown in Figure 10. Housed in the cylinder is a powerful magnet, a radiowave emitter, and a radio-wave detector. Protons in hydrogen atoms in bones and soft tissue behave like magnets and align with the strong magnetic field. Energy from radio-waves causes some of the protons to flip their alignment. As the protons flip, they release radiant energy. A radio receiver detects this released energy. The amount of energy a proton releases depends on the type of tissue it is part of. The released energy detected by the radio receiver is used to create a map of the different tissues. A picture of the inside of the patient's body is produced painlessly.

#### **Infrared Waves**

Most of the warm air in a fireplace moves up the chimney, yet when you stand in front of a fireplace, you feel the warmth of the blazing fire. Why do you feel the heat? The warmth you feel is thermal energy transmitted to you by infrared waves, which are a type of electromagnetic wave with wavelengths between about one millimeter and 750 billionths of a meter.

You use infrared waves every day. A remote control emits infrared waves to control your television. A computer uses infrared waves to read CD-ROMs. In fact, every object emits infrared waves. Hotter objects emit more infrared waves than cooler objects emit. The wavelengths emitted also become shorter as the temperature increases. Infrared detectors can form images of objects from the infrared radiation they emit. Infrared sensors on satellites can produce infrared images that can help identify the vegetation over a region. **Figure 11** shows how cities appear different from surrounding vegetation in infrared satellite imagery.



This infrared image of the same area was taken from a satellite. In this image, vegetation is red and buildings are gray.

# **Visible Light**

Visible light is the range of electromagnetic waves that you can detect with your eyes. Light differs from radio waves and infrared waves only by its frequency and wavelength. Visible light has wavelengths around 750 billionths to 400 billionths of a meter. Your eyes contain substances that react differently to various wavelengths of visible light, so you see different colors. These colors range from long-wavelength red to short-wavelength blue. If all the colors are present, you see the light as white.

#### **Ultraviolet Waves**

Ultraviolet waves are electromagnetic waves with wavelengths from about 400 billionths to 10 billionths of a meter. Ultraviolet waves are energetic enough to enter skin cells. Overexposure to ultraviolet rays can cause skin damage and cancer. Most of the ultraviolet radiation that reaches Earth's surface is longer-wavelength UVA rays. The shorter-wavelength UVB rays cause sunburn, and both UVA and UVB rays can cause skin cancers and skin damage such as wrinkling. Although too much exposure to the Sun's ultraviolet waves is damaging,

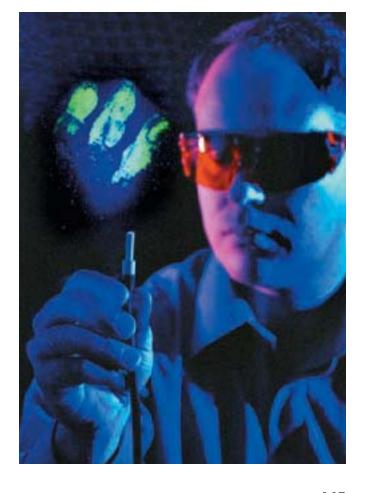
some exposure is necessary. Ultraviolet light striking the skin enables your body to make vitamin D, which is needed for healthy bones and teeth.

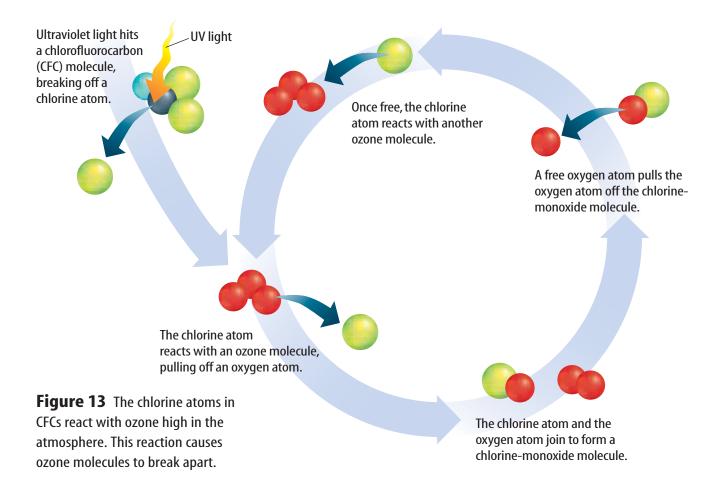
**Useful UVs** A useful property of ultraviolet waves is their ability to kill bacteria on objects such as food and medical supplies. When ultraviolet light enters a cell, it damages protein and DNA molecules. For some singlecelled organisms, damage can mean death, which can be a benefit to human health. Ultraviolet waves are also useful because they make some materials fluoresce. Fluorescent materials absorb ultraviolet waves and reemit the energy as visible light. As shown in **Figure** 12, police detectives sometimes use fluorescent powder to show fingerprints when solving crimes.

**Figure 12** The police detective in this picture is shining ultraviolet light on a fingerprint dusted with fluorescent powder.

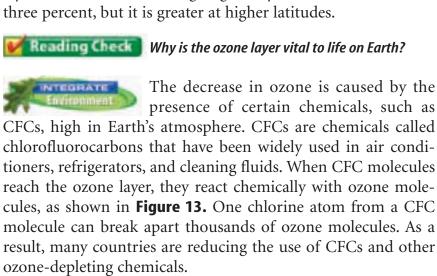


CT Scans In certain situations, doctors will perform a computerized tomography (CT) scan on a patient instead of taking a traditional X ray. Research to find out more about CT scans. Compare and contrast CT scans with X rays. What are the advantages and disadvantages of a CT scan? Write a paragraph about your findings in your Science Journal.





**The Ozone Layer** About 20 to 50 km above Earth's surface in the stratosphere is a region called the ozone layer. Ozone is a molecule composed of three oxygen atoms. It is continually being formed and destroyed by ultraviolet waves high in the atmosphere. The ozone layer is vital to life on Earth because it absorbs most of the Sun's harmful ultraviolet waves. However, over the past few decades, the amount of ozone in the ozone layer has decreased. Averaged globally, the decrease is about three percent, but it is greater at higher latitudes.



# **X Rays and Gamma Rays**

The electromagnetic waves with the shortest wavelengths and highest frequencies are X rays and gamma rays. Both X rays and gamma rays are high-energy electromagnetic waves. X rays have wavelengths between about 10 billionths of a meter and 10 trillionths of a meter. Doctors and dentists use low doses of X rays to form images of internal organs, bones, and teeth, like the image shown in **Figure 14.** X rays also are used in airport screening devices to examine the contents of luggage.

Electromagnetic waves with wavelengths shorter than about 10 trillionths of a meter are **gamma rays**. These are the highestenergy electromagnetic waves and can penetrate through several centimeters of lead. Gamma rays are produced by processes that occur in atomic nuclei. Both X rays and gamma rays are used in a technique called radiation therapy to kill diseased cells in the human body. A beam of X rays or gamma rays can damage the biological molecules in living cells, causing both healthy and diseased cells to die. However, by carefully controlling the amount of X-ray or gamma-ray radiation received by the diseased area, the damage to healthy cells can be reduced.



**Figure 14** Bones are more dense than surrounding tissues and absorb more X rays. The image of a bone on an X ray is the shadow cast by the bone as X rays pass through the soft tissue.

# section

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#### **Summary**

#### **Radio Waves and Infrared Waves**

- Radio waves are electromagnetic waves with wavelengths longer than about 1 mm.
- Microwaves are radio waves with wavelengths between about 30 cm and 1 mm.
- Infrared waves have wavelengths between about 1 mm and 750 billionths of a meter.

#### **Visible Light and Ultraviolet Waves**

- Visible light waves have wavelengths between about 750 and 400 billionths of a meter.
- Ultraviolet waves have wavelengths between about 400 and 10 billionths of a meter.
- Most of the harmful ultraviolet waves emitted by the Sun are absorbed by the ozone layer.

#### **X Rays and Gamma Rays**

- X rays and gamma rays are the most energetic electromagnetic waves.
- Gamma rays have wavelengths less than 10 trillionths of a meter and are produced in the nuclei of atoms.

#### Self Check

- **1. Explain** A mug of water is heated in a microwave oven. Explain why the water gets hotter than the mug.
- 2. Describe why you can see visible light waves but not other electromagnetic waves.
- 3. List the beneficial effects and the harmful effects of human exposure to ultraviolet rays.
- 4. Identify three objects in a home that produce electromagnetic waves and describe how the electromagnetic waves are used.
- 5. Think Critically What could an infrared image of their house reveal to homeowners?

#### **Applying Math**

- 6. Use Scientific Notation Express the range of wavelengths corresponding to visible light, ultraviolet waves, and X rays in scientific notation.
- **7. Convert Units** A nanometer, abbreviated nm, equals one billionth of a meter, or  $10^{-9}$  m. Express the range of wavelengths corresponding to visible light, ultraviolet waves, and X rays in nanometers.



# The Shape of Satellite Dishes

Communications satellites transmit signals with a narrow beam pointed toward a particular area of Earth. To detect this signal, receivers are typically large, parabolic dishes.



How does the shape of a satellite dish improve reception?

#### Goals

- Make a model of a satellite reflecting dish.
- Observe how the shape of the dish affects reception.

#### **Materials**

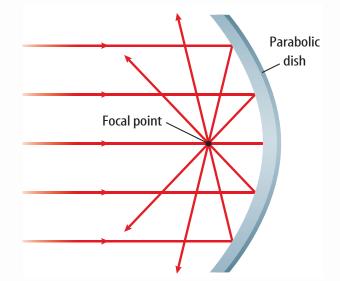
flashlight small bowl several books \*large, metal spoon aluminum foil \*Alternate materials

#### Safety Precautions 🗪 🎏 📶





- 1. Complete the safety form.
- Cover one side of a book with aluminum foil. Be careful not to wrinkle the foil.
- **3.** Line the inside of the bowl with foil, also keeping it as smooth as possible.
- 4. Place some of the books on a table. Put the flashlight on top of the books so that its beam of light will shine several centimeters above and across the table.
- 5. Hold the foil-covered book on its side at a right angle to the top of the table. The foilcovered side should face the beam of light.



- **6. Observe** the intensity of the light on the foil.
- 7. Repeat steps 5 and 6, replacing the foilcovered book with the bowl.

# Conclude and Apply

- 1. Compare the brightness of the light reflected from the two surfaces.
- 2. Explain why the light you see from the curved surface is brighter.
- 3. Infer why bowl-shaped dishes are used to receive signals from satellites.



Compare your conclusions with those of other students in your class. For more help, refer to the Science Skill Handbook.

# **Radio Communication**

# **Reading Guide**

#### What You'll Learn

- **Explain** how modulating carrier waves enables information to be transmitted by radio waves.
- **Distinguish** between amplitude modulation and frequency modulation.
- Identify various ways of communicating using radio waves.

# Why It's Important

Every day, you use radio waves to communicate.

#### Review Vocabulary

modulate: to vary the amplitude or frequency of a wave to transmit information

#### **New Vocabulary**

- carrier wave
- cathode-ray tube
- transceiver
- Global Positioning System (GPS)

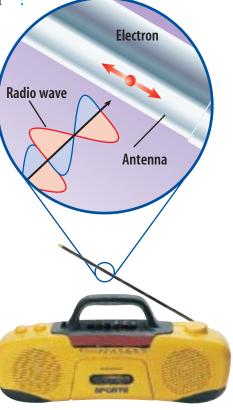
#### **Radio Transmission**

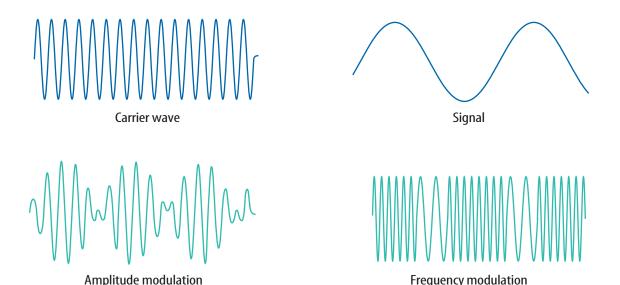
When you listen to the radio, you hear music and words that are produced at a distant location. The music and words are sent to your radio by radio waves. The metal antenna of your radio detects radio waves. As the electromagnetic waves pass by your radio's antenna, the electrons in the metal vibrate, as shown in **Figure 15.** These vibrating electrons produce a changing electric current that contains the information about the music and words. An amplifier boosts the current and sends it to speakers, causing them to vibrate. The vibrating speakers create sound waves that travel to your ears. Your brain interprets these sound waves as music and words

**Dividing the Radio Spectrum** Each radio station is assigned to broadcast at one particular radio frequency. Turning the tuning knob on your radio allows you to select a particular frequency to listen to. The specific frequency of the electromagnetic wave that a radio station is assigned is called the carrier wave.

The radio station must do more than simply transmit a carrier wave. The station has to send information about the sounds that you are to receive. This information is sent by modifying the carrier wave. The carrier wave is modified to carry information in one of two ways, as shown in **Figure 16.** 

Figure 15 Radio waves exert a force on the electrons in an antenna, causing the electrons to vibrate.



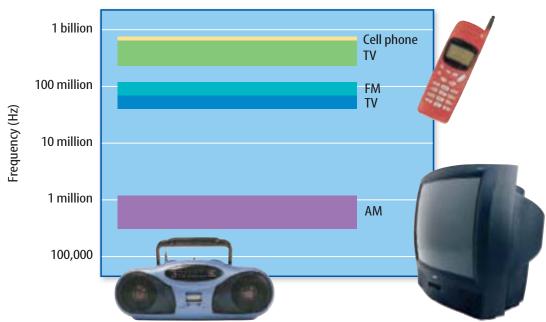


**Figure 16** A carrier wave broadcast by a radio station can be altered in one of two ways to transmit a signal: amplitude modulation (AM) or frequency modulation (FM).

**AM Radio** An AM radio station broadcasts information by varying the amplitude of the carrier wave, as shown in **Figure 16.** Your radio detects the variations in amplitude of the carrier wave and produces a changing electric current from these variations. The changing electric current makes the speaker vibrate. AM carrier-wave frequencies range from 540,000 to 1,600,000 Hz.

**FM Radio** Electronic signals are transmitted by FM radio stations by varying the frequency of the carrier wave, as in **Figure 16.** Your radio detects the changes in frequency of the carrier wave. Because the strength of the FM waves is kept fixed, FM signals tend to be more clear than AM signals. FM carrier frequencies range from 88 million to 108 million Hz. This is much higher than AM frequencies, as shown in Figure 17. Figure 18 shows how radio signals are broadcast.

Figure 17 Cell phones, TVs, and radios broadcast at frequencies that range from more than 500,000 Hz to almost 1 billion Hz.



### **NATIONAL** GEOGRAPHIC VISUALIZING RADIO BROADCASTS

#### Figure 18

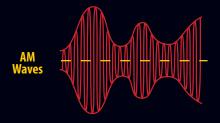
ou flick a switch, turn the dial, and music from your favorite radio station fills the room. Although it seems like magic, sounds are transmitted over great distances by converting sound waves to electromagnetic waves and back again, as shown here.

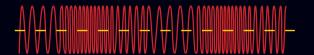


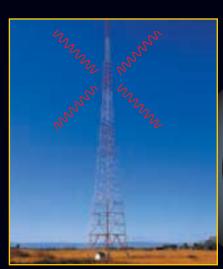


At the radio station, musical instruments and voices create sound waves by causing air molecules to vibrate. Microphones convert these sound waves to a varying electric current, or electronic signal.

B This signal then is added to the station's carrier wave. If the station is an AM station, the electronic signal modifies the amplitude of the carrier wave. If the station is an FM station, the electronic signal modifies the frequency of the carrier wave.







The modified carrier wave is used to vibrate electrons in the station's antenna. These vibrating electrons create a radio wave that travels out in all directions at the speed of light.



The radio wave from the station makes electrons in your radio's antenna vibrate. This creates an electric current. If your radio is tuned to the station's frequency, the carrier wave is removed from the original electronic signal. This signal then makes the radio's speaker vibrate, creating sound waves that you hear as music.



**Astronomers** Do you ever look up at the stars at night and wonder how they were formed? With so many stars and so many galaxies, life might be possible on other planets. Research ways that astronomers use electromagnetic waves to investigate the universe. Choose one project astronomers currently are working on that interests you, and write about it in your Science Journal. Discuss the benefits of a career in astronomy.

#### **Television**

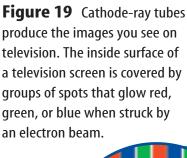
What would people hundreds of years ago have thought if they had seen a television? Televisions might seem like magic, but not if you know how they work. Television and radio transmissions are similar. At the television station, sounds and images are changed into electronic signals. These signals are broadcast by carrier waves. The audio part of television is sent by FM radio waves. Information about the color and brightness is sent at the same time by AM signals.

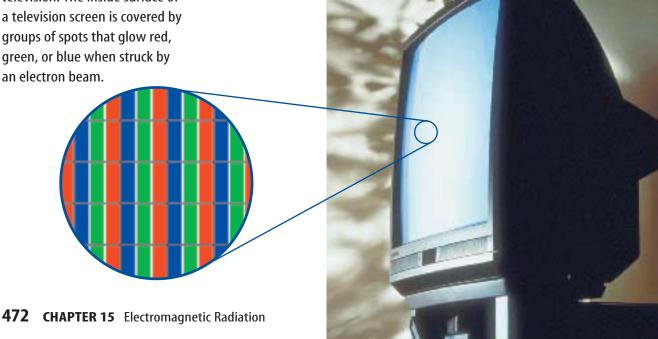
**Cathode-Ray Tubes** In many television sets, images are displayed on a cathode-ray tube (CRT), as shown in Figure 19. A cathode-ray tube is a sealed vacuum tube in which one or more beams of electrons are produced. The CRT in a color TV produces three electron beams that are focused by a magnetic field and strike a coated screen. The screen is speckled with more than 100,000 rectangular spots that are of three types. One type glows red, another glows green, and the third type glows blue when electrons strike it. The spots are grouped together, with a red, green, and blue spot in each group.

An image is created when the three electron beams of the CRT sweep back and forth across the screen. Each electron beam controls the brightness of each type of spot, according to the information in the video signal from the TV station. By varying the brightness of each spot in a group, the three spots together can form any color so that you see a full-color image.



Reading Check What is a cathode-ray tube?





## **Telephones**

Until about 1950, human operators were needed to connect telephone calls between people. Just 20 years ago, you never would have seen someone walking down the street talking on a telephone. Today, cell phones are seen everywhere. When you speak into a telephone, a microphone converts sound waves into an electrical signal. In cell phones, this current is used to create radio waves that are transmitted to and from a microwave tower, as shown in **Figure 20.** A cell phone uses one radio signal for sending information to a tower at a base station. It uses another signal for receiving information from the base station. The base stations are several kilometers apart. The area each one covers is called a cell. If you move from one cell to another while using a cell phone, an automated control station transfers your signal to the new cell.



Reading Check What are the cells in a cell-phone system?

**Cordless Telephones** Like a cellular telephone, a cordless telephone is a transceiver. A transceiver transmits one radio signal and receives another radio signal from a base unit. Having two signals at different frequencies allows you to talk and listen at the same time. Cordless telephones work much like cell phones. With a cordless telephone, however, you must be close to the base unit. Another drawback is that when someone nearby is using a cordless telephone, you could hear that conversation on your phone if the frequencies match. For this reason, many cordless phones have a channel button. This allows you to switch your call to another frequency.

**Pagers** Another method of transmitting signals is a pager, which allows messages to be sent to a small radio receiver. A caller leaves a message at a central terminal by entering a callback number through a telephone keypad or by entering a text message from a computer. At the terminal, the message is changed into an electronic signal and transmitted by radio waves. Each pager is given a unique number for identification. This identification number is sent along with the message. Your pager receives all messages that are transmitted in the area at its assigned frequency. However, your pager responds only to messages with its particular identification number. Newer pagers can send data as well as receive them.

Figure 20 The antenna at the top of a microwave tower receives signals from nearby cell phones. **Determine** whether any microwave towers are located near your school or home. Describe their locations.



#### **Topic: Radio Wave Technology**

Visit **gpescience.com** for Web links to information about advances in radio-wave technology.

**Activity** List the advances you find, and write about the significance of each one in your Science Journal.

Figure 21 Communications satellites, like the one shown here, use solar panels to provide the electrical energy they need to communicate with receivers on Earth. The solar panels are the structures on either side of the central body of the satellite.



# **Communications Satellites**

Since satellites were first developed, thousands have been launched into Earth's orbit. Many of these, like the one in Figure 21, are used for communication. A station broadcasts a high-frequency microwave signal to the satellite. The satellite receives the signal, amplifies it, and transmits it to a particular region on Earth. To avoid interference, the frequency broadcast by the satellite is different from the frequency broadcast from Earth.

**Satellite Telephone Systems** If you have a mobile telephone, you can make a phone call when sailing across the ocean. To make a call on a mobile telephone, the telephone transmits radio waves directly to a satellite. The satellite relays the signal to a ground station, and the call is passed on to the telephone network. Satellite links work well for one-way transmissions, but two-way communications can have an annoying delay caused by the large distance the signals must travel to and from the satellite.

**Television Satellites** The satellite-reception dishes that you sometimes see in yards or attached to houses are receivers for television satellite signals. Satellite television is used as an alternative to ground-based transmission. Television satellites use microwaves rather than the longer-wavelength radio waves used for normal television broadcasts. Short-wavelength microwaves travel more easily through the atmo-sphere. The ground receiver dishes are rounded to help focus the microwaves onto an antenna.



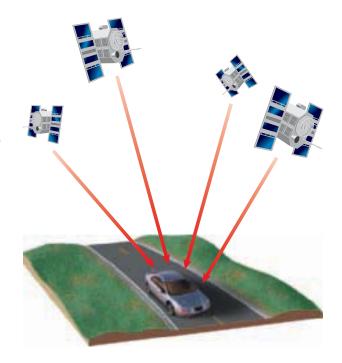
**Topic: Satellite Communication** 

Visit gpescience.com for Web links to information about ways satellites are used for communication.

**Activity** Write a paragraph describing the advantages of placing a communications satellite in a geosynchronus orbit. Include a diagram.

# **The Global Positioning System**

Getting lost while hiking is not uncommon, but if you are carrying a Global Positioning System receiver, this is much less likely to happen. The Global Positioning System (GPS) is a system of satellites, ground monitoring stations, and receivers that determine a person's or object's exact location at or above Earth's surface. The 24 satellites necessary for 24-hour, around-the-world coverage became fully operational in 1995. GPS satellites are owned and operated by the United States Department of Defense, but the microwave signals they send out can be used by anyone. As shown in **Figure 22**, signals from four satellites are needed to determine the location of an object using a GPS receiver. Today, GPS receivers are used in airplanes, ships, cars, and even by hikers.



**Figure 22** A GPS receiver uses signals from orbiting satellites to determine the receiver's location.

#### section гечіеш

#### **Summary**

#### **Radio Transmission**

- Radio stations transmit electromagnetic waves that receivers convert to sound waves.
- Each AM radio station is assigned a carrierwave frequency and varies the amplitude of the carrier waves to transmit a signal.
- Each FM radio station is assigned a carrierwave frequency and varies the frequency of the carrier waves to transmit a signal.

#### **Television**

 TV sets use cathode-ray tubes to convert electronic signals from TV stations into both sounds and images.

#### **Telephones**

- Telephones contain transceivers that convert sound waves into electrical signals and also convert electrical signals into sound waves.
- Wires, microwave towers, and satellites are used to transmit and receive telephone signals.

#### **Global Positioning System (GPS)**

 The GPS uses a system of satellites to determine a person's or object's exact position.

#### **Self Check**

- 1. Explain the difference between AM and FM radio. Make a sketch of how a carrier wave is modulated in AM and FM radio.
- 2. **Define** a cathode-ray tube, and explain how it is used in a television.
- 3. **Describe** what happens if you are talking on a cell phone while riding in a car and you travel from one cell to another cell.
- 4. Explain some of the uses of the Global Positioning System. Why might emergency vehicles be equipped with GPS receivers?
- 5. Think Critically Why do cordless telephones stop working if you move too far from the base unit?

#### **Applying Math**

6. Calculate a Ratio A group of red, green, and blue spots on a TV screen is a pixel. A standard TV has 460 pixels horizontally and 360 pixels vertically. A high-definition TV has 1,920 horizontal and 1,080 vertical pixels. What is the ratio of the number of pixels in a high-definition TV to the number in a standard TV?



# **Use the Internet**

# Rad % Frequencies

#### Goals

- Research which frequencies are used by different radio stations.
- **Observe** the reception of your favorite radio station.
- Make a chart of your findings and communicate them to other students.

#### **Data Source** Internet Lab

Visit **gpescience.com** for more information on radio frequencies, different frequencies of radio stations around the country, and the ranges of AM and FM broadcasts.

#### 🔊 Real-World Problem

The signals from many radio stations broadcasting at different frequencies are hitting your radio's antenna at the same time. When you tune to your favorite station, the electronics inside your radio amplify the signal at the frequency broadcast by the station. The signal from your favorite station is broadcast from a transmission site that may be several miles away.

You may have noticed that if you're listening to a radio station while driving in a car, sometimes the station gets fuzzy and you hear another station at the same time. Sometimes you lose the station completely. How far can you drive before this happens? Does the distance vary depending on the station you listen to? What are the ranges of radio stations? Form a hypothesis about how far you think a radio station can transmit. Which type of signal, AM or FM, has a greater range? Form a hypothesis about the range of your favorite radio station.

### 🤼 Make a Plan

- 1. Research what frequencies are used by AM and FM radio stations in your area and other areas around the country.
- **2. Determine** these stations' broadcast locations.
- **3. Determine** the broadcast range of radio stations in your area.
- **4. Observe** how frequencies differ. What is the maximum difference between frequencies for FM stations in your area? AM stations?



# Using Scientific Methods

#### Follow Your Plan

- Make sure your teacher approves your plan before you start.
- Visit the Web site shown below for links to different radio stations.
- **3. Compare** the different frequencies of the stations and the locations of the broadcasts.
- **4. Determine** the range of radio stations in your area and the power of their broadcast signals in watts.
- 5. Record your data in your Science Journal.

# Analyze Your Data

- **1. Make** a map of the radio stations in your area. Do the ranges of AM stations differ from those of FM stations?
- **2. Make** a map of different radio stations around the country. Do you see any patterns in the frequencies for stations that are located near each other?
- **3. Write** a description that compares how close the frequencies of AM stations are and how close the frequencies of FM stations are. Also compare the power of their broadcast signals and their ranges.
- 4. Share your data by posting it at the Web site shown below.

# Conclude and Apply-

- 1. Compare your findings with those of your classmates and other data that are posted at the Web site shown below. Do all AM stations and FM stations have different ranges?
- 2. Observe your map of the country. How close can stations with similar frequencies be? Do AM and FM stations appear to be different in this respect?
- 3. Infer The power of a broadcast signal also determines its range. How does the power (wattage) of the signals affect your analysis of your data?



# ommunicating

Find this lab using the Web site below. Post your data in the table provided. **Compare** your data with those of other students. Then combine your data with theirs and make a map for your class that shows all of the data.

Internet Lab gpescience.com



# **Einstein and the Special Theory of Relativity**

#### **Catch a Wave**

At age 16, Albert Einstein wondered, "What would it be like to ride a beam of light?" He imagined what might happen if he turned on a flashlight while riding a light beam. Because the flashlight already would be traveling at the speed of light, would light from the flashlight travel at twice the speed of light?

#### What's so special?

Einstein thought about this problem, and in 1905, he published the special theory of relativity. This theory states that the speed of light will

be the same when measured by any observer that moves with a constant speed. The measured speed of light will not depend on the speed of the observer or on how fast the source of light is moving. Einstein answered the question he had

asked himself when he was 16. He found the universal speed limit that can't be broken.

#### It Doesn't Add Up

According to Einstein, electromagnetic waves such as light waves behave very differently from other waves. For example, sound waves from the siren of an ambulance moving toward you move faster than they would if the ambulance were not moving. The speed of the ambulance adds to the speed of the sound waves. However, for light waves, the speed of a light source doesn't add to the speed of light.

#### **Very Strange, but True**

Einstein's special theory of relativity makes other strange predictions. According to this theory, no object can travel faster than the speed of light. Another prediction is that the measured length of a moving object is shorter than when the object is at rest. Also, moving clocks should run more slowly than when they are at rest. These predictions have been confirmed by experiments. Measurements have shown, for example, that a moving clock does run more slowly.

**Communicate** Research the life of Albert Einstein and make a time line showing important events in his life. Also include on your time line major historical events that occurred during Einstein's lifetime.



#### Reviewing Main Ideas

#### **Section 1**

# What are electromagnetic

1. Electromagnetic waves consist of vibrating electric and magnetic fields, and are produced by vibrating electric charges.



- **2.** Electromagnetic waves carry radiant energy and can travel through a vacuum or through matter.
- **3.** Electromagnetic waves sometimes behave like particles called photons.

# **Section 2**

#### The Electromagnetic **Spectrum**

1. Electromagnetic waves with the longest wavelengths are called radio waves. Radio



- waves have wavelengths greater than about 1 mm. Microwaves are radio waves with wavelengths between about 30 cm and 1 mm.
- **2.** Infrared waves have wavelengths between about 1 mm and 750 billionths of a meter. Warmer objects emit more infrared waves than cooler objects do.

- **3.** Visible light rays have wavelengths between about 750 and 400 billionths of a meter. Substances in your eyes react with visible light to enable you to see.
- **4.** Ultraviolet waves have frequencies between about 400 and 10 billionths of a meter. Excessive exposure to ultraviolet waves can damage human skin.
- **5.** X rays and gamma rays are high-energy electromagnetic waves with wavelengths less than 10 billionths of a meter. X rays are used in medical imaging.

#### **Section 3** Radio Communication

- 1. Modulated radio waves are used often for communication. AM and FM are two forms of carrierwave modulation.
- **2.** Television signals are transmitted as a combination of AM and FM waves.



- **3.** Cellular telephones, cordless telephones, and pagers use radio waves to transmit signals. Communications satellites are used to relay telephone and television signals over long distances.
- **4.** The Global Positioning System (GPS) enables the exact position of a person or object on Earth to be determined.

FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review electromagnetic radiation.

#### **Using Vocabulary**

carrier wave p. 469
cathode-ray tube p. 472
electromagnetic wave
p. 456
gamma ray p. 467
Global Positioning System
(GPS) p. 475
infrared wave p. 464

microwave p. 463 photon p. 460 radiant energy p. 459 radio wave p. 463 transceiver p. 473 ultraviolet wave p. 465 visible light p.462 X ray p. 467

Complete each statement using the correct word or phrase from the vocabulary list above.

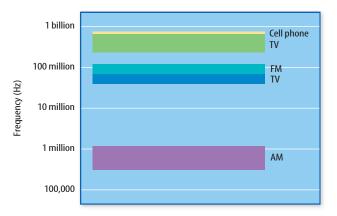
- **1.** \_\_\_\_\_ are the type of electromagnetic waves often used for communication.
- **2.** A remote control uses \_\_\_\_\_\_ to communicate with a television set.
- **3.** Electromagnetic waves transmit \_\_\_\_\_.
- **4.** If you stay outdoors too long, your skin might be burned by exposure to \_\_\_\_\_ from the Sun.
- **5.** A radio station broadcasts radio waves called \_\_\_\_\_\_, which have the specific frequency assigned to the station.
- **6.** The image on a television screen is produced by a \_\_\_\_\_.
- **7.** Transverse waves that are produced by vibrating electric charges and consist of vibrating electric and magnetic fields are \_\_\_\_\_.

#### **Checking Concepts**

Choose the word or phrase that best answers each question.

- **8.** Which type of electromagnetic wave is the most energetic?
  - **A)** gamma rays
  - **B)** ultraviolet waves
  - **c)** infrared waves
  - **D)** microwaves

Use the figure below to answer question 9.



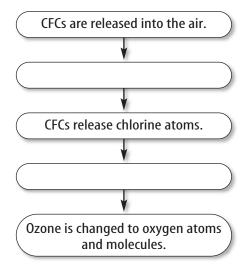
- **9.** What signal has the longest wavelength?
  - **A)** cell phone
- **c)** FM
- B) TV
- D) AM
- **10.** Which type of electromagnetic wave enables skin cells to produce vitamin D?
  - **A)** visible light
  - **B)** ultraviolet waves
  - () infrared waves
  - **D)** X rays
- **11.** Which of the following describes X rays?
  - A) short wavelength, high frequency
  - **B)** short wavelength, low frequency
  - c) long wavelength, high frequency
  - **D)** long wavelength, low frequency
- **12.** Which of the following is changing in an AM radio wave?
  - A) speed
- **C)** amplitude
- **B)** frequency
- **D)** wavelength
- **13.** Which type of electromagnetic wave has wavelengths greater than about 1 mm?
  - A) X rays
- **c)** gamma rays
- **B)** radio waves
- **D)** ultraviolet waves
- **14.** Which of these colors of visible light has the shortest wavelength?
  - **A)** blue
- **c)** red
- **B)** green
- **D)** white

#### **Interpreting Graphics**

**15.** Copy and complete the following table about the electromagnetic spectrum.

Uses of Electromagnetic Waves		
Type of Electromagnetic Waves	Examples of How Electromagnetic Waves Are Used	
	radio, TV transmission	
Infrared waves	Do not write in this book.	
Visible light	vision	
	fluorescent materials	
X rays		
	destroying harmful cells	

**16.** Copy and complete the following events chain about the destruction of ozone molecules in the ozone layer by CFC molecules.



#### **Thinking Critically**

- 17. Explain why X rays are used in medical imaging.
- **18. Predict** whether an electromagnetic wave would travel through space if its electric and magnetic fields were not changing with time. Explain your reasoning.

- **19. Infer** Electromagnetic waves consist of vibrating electric and magnetic fields. A magnetic field can move a compass needle. Why doesn't a compass needle move when visible light strikes the compass?
- **20.** Classify Look around your home, school, and community. Make a list of the different devices that use electromagnetic waves. Beside each device, write the type of electromagnetic wave the device uses.
- **21.** Form a hypothesis to explain why communications satellites don't use ultraviolet waves to receive information and transmit signals to Earth's surface.
- **22. Compare** the energy of photons corresponding to infrared waves with the energy of photons corresponding to ultraviolet waves.
- **23. Determine** whether or not all electromagnetic waves always travel at the speed of light. Explain.

#### **Applying Math**

- **24.** Use Fractions When visible light waves travel in ethyl alcohol, their speed is three-fourths of the speed of light in air. What is the speed of light in ethyl alcohol?
- **25.** Use Scientific Notation The speed of light in a vacuum has been determined to be 299,792,458 m/s. Express this number to four significant digits using scientific notation.
- **26.** Calculate Wavelength A radio wave has a frequency of 540,000 Hz and travels at a speed of 300,000 km/s. Use the wave speed equation to calculate the wavelength of the radio wave. Express your answer in meters.

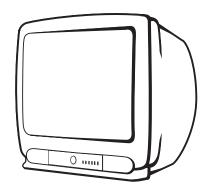
# chapter 15 Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### Multiple Choice

- **1.** Which of the following produces electromagnetic waves?
  - A. vibrating charge
  - B. constant electric field
  - **c.** static charge
  - D. constant magnetic field

#### Use the illustration below to answer questions 2 and 3.



- **2.** A television image is produced by three electron beams. What device inside a television set produces the electron beams?
  - **A.** transceiver
  - B. transmitter
  - **C.** antenna
  - **D.** cathode-ray tube

#### Test-Taking Tip

**Marking on Tests** Be sure to ask if it is okay to write on the test booklet when taking the test, but make sure you mark all answers on your answer sheet.

- **3.** What colors are the three types of glowing spots that form the different colors on the television screen?
  - A. red, yellow, blue
  - B. red, green, blue
  - **C.** cyan, magenta, yellow
  - D. cyan, magenta, blue
- **4.** Which of the following explains how interference is avoided between the signals communications satellites receive and the signals they broadcast?
  - **A.** The signals travel at different speeds.
  - **B.** The signals have different amplitudes.
  - **c.** The signals have different frequencies.
  - **D.** The signals are only magnetic.

#### Use the table below to answer questions 5 and 6.

Regions of the Electromagnetic Spectrum		
Infrared waves	Radio waves	Gamma rays
X rays	Visible light	Ultraviolet waves

- **5.** If you arranged the list of electromagnetic waves shown above in order from shortest to longest wavelength, which would be first on the list?
  - **A.** radio waves
  - B. X rays
  - **c.** gamma rays
  - **D.** visible light

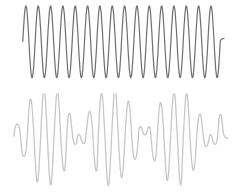
- **6.** Which region of the electromagnetic spectrum listed in the table above includes microwaves?
  - A. gamma rays
  - **B.** radio waves
  - **C.** ultraviolet waves
  - **D.** infrared waves
- **7.** The warmth you feel when you stand in front of a fire is thermal energy transmitted to you by what type of electromagnetic waves?
  - **A.** X rays
  - **B.** microwaves
  - **c.** ultraviolet waves
  - **D.** infrared waves

#### **Gridded Response**

**8.** Electromagnetic radiation travels through space at  $3.00 \times 10^5$  km/s. The moon is, on average, 382,000 km from Earth. How many seconds would it take radio waves broadcast from Earth to reach the moon?

#### Short Response

Use the illustrations below to answer question 9.



- **9.** The illustrations above show two radio waves broadcast by a radio station. The upper, unmodulated wave is the carrier wave. The lower figure shows the same wave that has been modulated to carry sound information. What type of modulation does it show?
- **10.** Even on a cloudy day, you can get sunburned outside. However, inside a glass greenhouse, you won't get sunburned. Based on this fact, which type of electromagnetic waves will pass through clouds but not glass?

#### **Extended Response**

**11.** Explain how an electromagnetic wave that strikes a material transfers radiant energy to the atoms in the material.

Use the illustration below to answer question 12.



- **12.** The illustration above shows a microwave interacting with water molecules in food.
  - Part A How does the electric field in microwaves affect water molecules?
  - **Part B** Describe how thermal energy is produced by microwaves interacting with water molecules inside food.

# chapter

# 16

#### BIG (Idea

The energy in an energy source is transformed into other forms of energy that are used by humans.

#### **16.1 Fossil Fuels**

MAIN (Idea Burning fossil fuels produces thermal energy that is converted into other useful forms of energy

#### 16.2 Nuclear Energy

MAIN (Idea Nuclear power plants convert thermal energy produced by the fission of uranium atoms into electrical energy.

# 16.3 Renewable Energy Sources

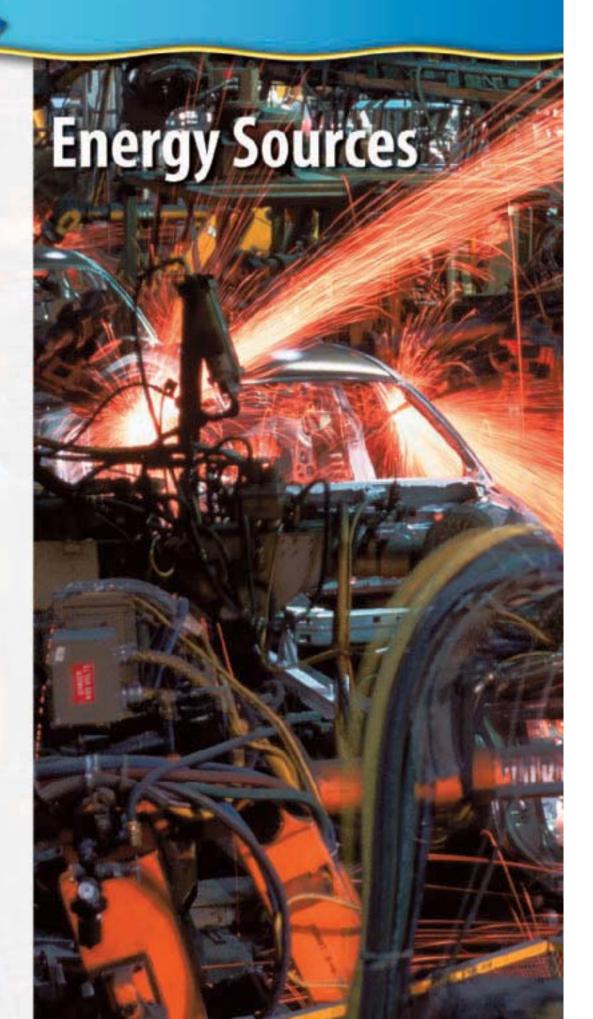
MAIN (Idea Renewable energy sources are not used up because they are replaced as they are used.

### Doing the Robot

A car uses the chemical energy in gasoline to make it run. But energy is also needed to make a car. For example, these welding robots use energy to join pieces of a car together. Even the materials that a car is made from, such as aluminum and plastic, are produced using energy.

#### **Science Journal**

Describe how your day would be different if the electric power were off all day.



# **Start-Up Activities**



#### **Heating with Solar Energy**

The Sun constantly bathes our planet with enormous amounts of energy. This energy can be captured and used to make electricity, heat homes, and provide hot water. How can the Sun's energy be used to heat water?



- 1. Complete the safety form.
- 2. Use scissors to poke a small hole in the center of each of two plastic coffee can lids.
- 3. Fill a coffee can that has been painted black with water at room temperature. Snap on the lid and push a thermometer through the hole in the lid. Record the temperature.
- **4.** Repeat step 3 using the coffee can that has been painted white.
- 5. Place both cans in direct sunlight. After 15 min, record the temperature of the water in both cans again.
- **6. Think Critically** Write a paragraph explaining why the temperature change differed between the two cans.



Preview this chapter's content and activities at gpescience.com



**Energy Sources** There are many sources of energy. Make the following Foldable to help

you organize information about various types of energy sources.

STEP 1

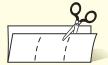
**Fold** a sheet of paper in half lengthwise. Make the back edge about 5 cm longer than the front edge.



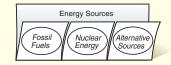
STEP 2 Turn the paper so the fold is on the bottom. Then fold it into thirds.



STEP 3 Unfold and cut only the top layer along both folds to make three tabs.



STEP 4 Label the Foldable as shown.



**Summarize** As you read this chapter, summarize important information about each type of energy source under the appropriate tab.



# **Fossil Fuels**

## **Reading Guide**

#### What You'll Learn

- Discuss properties and uses of fossil fuels.
- **Explain** how fossil fuels are formed.
- **Describe** how the chemical energy in fossil fuels is converted into electrical energy.

## Why It's Important

Fossil fuels are used to generate most of the energy you use every day.

#### Review Vocabulary

chemical potential energy: the energy stored in the chemical bonds between atoms in molecules

#### **New Vocabulary**

- fossil fuel
- petroleum
- nonrenewable resource

# **Using Energy**

How many different ways have you used energy today? Today you might have ridden in a car or bus, or used a hair dryer or a toaster. If you did, you used energy. Furnaces and stoves use thermal energy to heat buildings and cook food. Air conditioners use electrical energy to move thermal energy outdoors. Cars and other vehicles use mechanical energy to carry people and materials from one part of the country to another.

**Transforming Energy** According to the law of conservation of energy, energy cannot be created or destroyed. Energy can only be transformed, or converted, from one form to another. To use energy means to transform one form of energy to another form of energy that can perform a useful function. For

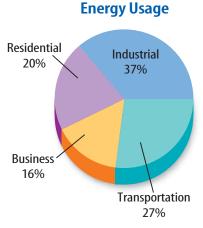
> example, energy is used when the chemical energy in fuels is transformed into thermal energy that heats your home.

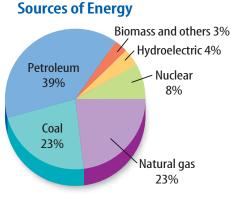
> Sometimes energy is transformed into a form that isn't useful. For example, power lines, like those shown in **Figure 1**, carry electrical energy. When electric current flows in power lines, about 10 percent of the electrical energy is transformed into thermal energy. This thermal energy flows into the air surrounding the power lines, and can no longer be used.

**Figure 1** Power lines like these carry the electrical energy you use every day.



**Energy Use in the United States** More energy is used in the United States than in any other country in the world. Figure 2 shows energy usage in the United States. About 20 percent of the energy is used in homes for heating and cooling, to run appliances, and to provide lighting and hot water. About 27 percent is used for transportation powering vehicles such as cars, trucks, and aircraft.





Another 16 percent is used by businesses to heat, cool, and light stores, shops, and office buildings. Finally, about 37 percent of this energy is used by industry and agriculture to manufacture products and produce food. Figure 2 also shows the main sources of the energy used in the United States. Almost 85 percent of the energy used in the United States comes from burning petroleum, natural gas, and coal. Nuclear power plants provide about eight percent of the energy used in the United States.

**Figure 2** These circle graphs show where energy is used in the United States and sources of this energy.

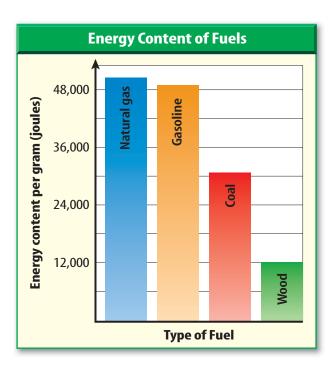
# **Making Fossil Fuels**

In one hour of freeway driving a car might use several gallons of gasoline. It may be hard to believe that it took millions of years to make the fuels that are used to produce electricity, provide heat, and transport people and materials. Figure 4 on the next page shows how coal, petroleum, and natural gas are formed by

the decay of ancient plants and animals. Fuels such as petroleum, or oil, natural gas, and coal are called fossil fuels because they are formed from the decaying remains of ancient plants and animals.

**Figure 3** The bar graph shows the amount of energy released by burning one gram of four different fuels. **Determine** the ratio of the energy content of natural gas to the energy content of wood.

**Concentrated Energy Sources** When fossil fuels are burned, carbon and hydrogen atoms combine with oxygen molecules in the air to form carbon dioxide and water molecules. This process converts the chemical potential energy that is stored in the chemical bonds between atoms to heat and light. Compared to other fuels such as wood, the chemical energy that is stored in fossil fuels is more concentrated. For example, burning 1 kg of coal releases two to three times as much energy as burning 1 kg of wood. Figure 3 compares the amount of energy that is produced by burning different fossil fuels.

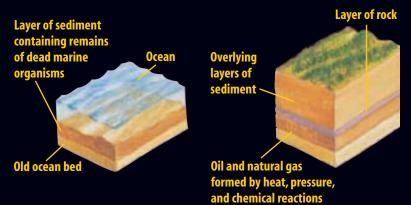


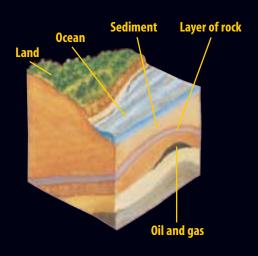
# NATIONAL VISUALIZING GEOGRAPHIC THE FORMATION OF FOSSIL FUELS

#### Figure 4

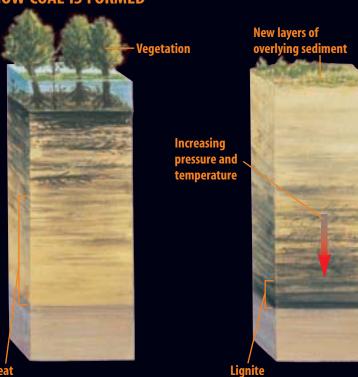
il and natural gas form when organic matter on the ocean floor, gradually buried under additional layers of sediment, is chemically changed by heat and crushing pressure. The oil and gas may bubble to the surface or become trapped beneath a dense rock layer. Coal forms when peat—partially decomposed vegetation—is compressed by overlying sediments and transformed first into lignite (soft brown coal) and then into harder, bituminous coal. These two processes are shown below.

#### **HOW OIL AND NATURAL GAS ARE FORMED**





#### **HOW COAL IS FORMED**





#### **Petroleum**

Millions of gallons of petroleum, or crude oil, are pumped every day from wells deep in Earth's crust. **Petroleum** is a highly flammable liquid formed by decayed ancient organisms, such as microscopic plankton and algae. Petroleum is a mixture of thousands of chemical compounds. Most of these compounds are hydrocarbons, which means their molecules contain only carbon atoms and hydrogen atoms.

**Separating Hydrocarbons** The different hydrocarbon molecules found in petroleum have different numbers and arrangements of carbon and hydrogen atoms. The composition and structure of hydrocarbons determines their properties.

The many different compounds that are found in petroleum are separated in a process called fractional distillation. This separation occurs in the tall towers of oil-refinery plants. First, crude oil is pumped into the bottom of the tower and heated. The chemical compounds in the crude oil boil and vaporize according to their individual boiling points. Materials with the lowest boiling points rise to the top of the tower as vapor and are collected. Hydrocarbons with high boiling points, such as asphalt and some types of waxes, remain liquid and are drained off through the bottom of the tower.

**WReading Checks** What is fractional distillation used for?

Other Uses for Petroleum Not all of the products obtained from petroleum are burned to produce energy. About 15 percent of the petroleum-based substances that are used in the United States go toward nonfuel uses. Look around at the materials in your home or classroom. Do you see any plastics? In addition to fuels, plastics and synthetic fabrics are made from the hydrocarbons found in crude petroleum. Also, lubricants such as grease and motor oil, as well as the asphalt used in surfacing roads, are obtained from petroleum. Some synthetic materials produced from petroleum are shown in **Figure 5.** 

**Figure 5** The objects shown here are made from chemical compounds found in petroleum.

**Identify** four objects in your classroom that are made from petroleum.



#### **Designing an Efficient Water Heater**

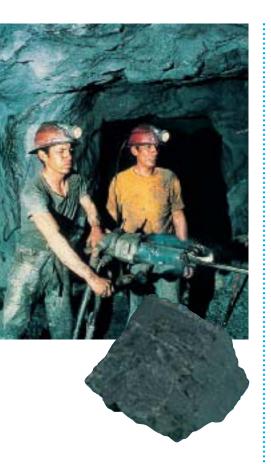
#### Procedure 🗫 🔑 🕲 🧦

- 1. Complete the safety form.
- 2. Measure and record the mass of a candle.
- 3. Measure 50 mL of water into a beaker. Record the temperature of the water.
- 4. Use the lighted candle to increase the temperature of the water by 10°C. Put out the candle and measure its mass.
- 5. Repeat steps 2 to 4 with an aluminum foil chimney surrounding the candle.

#### **Analysis**

- 1. Compare the mass change in the two trials. Which heater was more efficient?
- 2. Explain why adding the chimney changed the efficiency of the water heater.





**Figure 6** Coal mines usually are located deep underground.

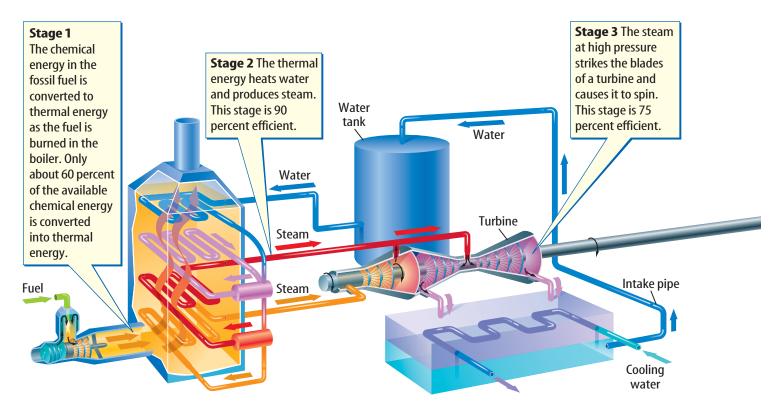
#### **Natural Gas**

The chemical processes that produce petroleum as ancient organisms decay also produce gaseous compounds called natural gas. These compounds rise to the top of the petroleum deposit and are trapped there. Natural gas is composed mostly of methane,  $CH_4$ , but it also contains other hydrocarbon gases such as propane,  $C_3H_8$ , and butane,  $C_4H_{10}$ . Natural gas is burned to provide energy for cooking, heating, and manufacturing. About one fourth of the energy consumed in the United States comes from burning natural gas. There's a good chance that your home has a stove, furnace, hot-water heater, or clothes drier that uses natural gas.

Natural gas contains more energy per kilogram than petroleum or coal does. It also burns more cleanly than other fossil fuels, produces fewer pollutants, and leaves no residue such as ash.

#### Coal

Coal is a solid fossil fuel that is found in mines underground, such as the one shown in **Figure 6.** In the first half of the twentieth century, most houses in the United States were heated by burning coal. In fact, during this time, coal provided more than half of the energy that was used in the United States. Now, almost two-thirds of the energy used comes from petroleum and natural gas, and only about one-fourth comes from coal. About 90 percent of all the coal that is used in the United States is burned by power plants to generate electricity.



**Origin of Coal** Coal mines were once the sites of ancient swamps. Coal formed from the organic material that was deposited as the plants that lived in these swamps died. Worldwide, the amount of coal that is potentially available is estimated to be 20 to 40 times greater than the supply of petroleum.

Coal also is a complex mixture of hydrocarbons and other chemical compounds. Compared to petroleum and natural gas, coal contains more impurities, such as sulfur and nitrogen compounds. As a result, more pollutants, such as sulfur dioxide and nitrogen oxides, are produced when coal is burned.

# **Generating Electricity**

Figure 7 shows that almost 70 percent of the electrical energy used in the United States is produced by burning fossil fuels. How is the chemical energy contained in fossil fuels converted to electrical energy in an electric power station?

The process is shown in **Figure 8.** In the first stage, fuel is burned in a boiler or combustion chamber, and it releases thermal energy. In the second stage, this thermal energy heats water and produces steam under high pressure. In the third stage, the steam strikes the blades of a turbine, causing it to spin. The shaft of the turbine is connected to an electric generator. In the fourth stage, electric current is produced when the spinning turbine shaft rotates magnets inside the generator. In the final stage, the electric current is transmitted to homes, schools, and businesses through power lines.

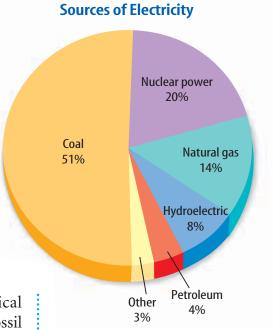


Figure 7 This circle graph shows the percentage of electricity generated in the United States that comes from various energy sources.

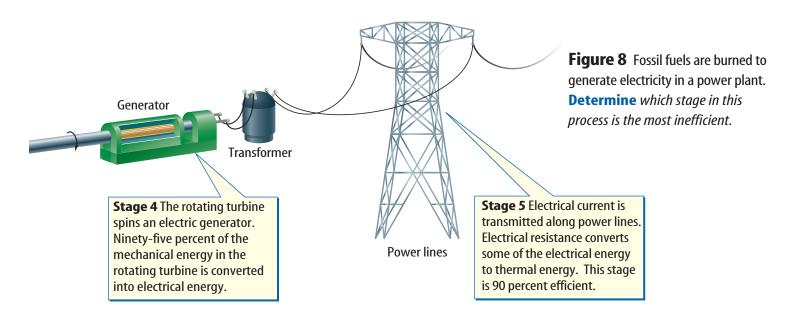


Table 1 Efficiency of Fossil Fuel Conversion		
Process	Efficiency (%)	
Chemical to thermal energy	60	
Conversion of water to steam	90	
Steam-turning turbine	75	
Turbine spins electric generator	95	
Transmission through power lines	90	
Overall efficiency	35	

# **Efficiency of Power Plants**

When fossil fuels are burned in power plants, not all of the chemical energy stored in the fuels is converted into electrical energy. In each energy transformation, some energy is converted into thermal energy that cannot be used. As a result, no stage of the process is 100 percent efficient.

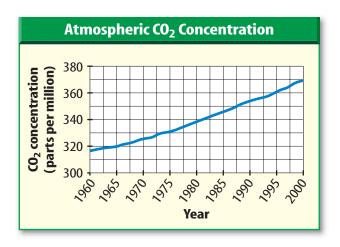
The efficiency of each stage of the process in a fossil-fuel burning power plant is given in **Table 1.** The overall efficiency is found by multiplying the efficiencies together, and is only about 35 percent. This means that only about

35 percent of the chemical energy contained in fossil fuels is converted into electrical energy by power plants. The other 65 percent is converted into thermal energy that is transferred to the environment.

# The Costs of Using Fossil Fuels

Although fossil fuels are a useful source of energy for generating electricity and providing the power for transportation, their use has some undesirable side effects. When petroleum products and coal are burned, smoke is given off that contains small particles called particulates. These particulates cause breathing problems for some people. Burning fossil fuels also releases carbon dioxide. **Figure 9** shows how the carbon dioxide concentration in the atmosphere has increased from 1960 to 2000. One consequence of increasing the atmospheric carbon dioxide concentration could be to cause Earth's surface temperature to increase.

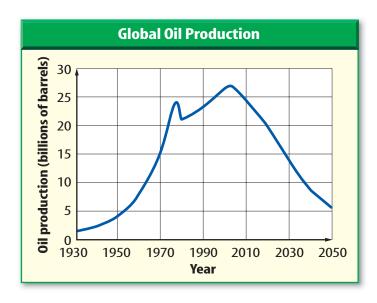
**Figure 9** The carbon dioxide concentration in Farth's atmosphere has been measured at Mauna Loa in Hawaii. From 1960 to 2000, the carbon dioxide concentration has increased by about 16 percent.



**Using Coal** The most abundant fossil fuel is coal, but coal contains even more impurities than oil or natural gas. Many electric power plants that burn coal remove some of these pollutants before they are released into the atmosphere. Removing sulfur dioxide, for example, helps to prevent the formation of compounds that might cause acid rain. Mining coal also can be dangerous. Miners risk being killed or injured, and some suffer from lung diseases caused by breathing coal dust over long periods of time.

#### **Nonrenewable Resources**

All fossil fuels are **nonrenewable resources**, which means they are resources that cannot be replaced by natural processes as quickly as they are used. Therefore, fossil fuel reserves are decreasing at the same time that population and industrial demands are increasing. Figure 10 shows how the production of oil might decline over the next 50 years as oil reserves are used up. As the production of energy from fossil fuels continues, the remaining reserves of fossil fuels will decrease. Fossil fuels will become more difficult to obtain, causing them to become more costly in the future.



**Figure 10** Some predictions show that worldwide oil production will peak by 2005 and then decline rapidly over the following 50 years.

# **Conserving Fossil Fuels**

Even as reserves of fossil fuels decrease and they become more costly, the demand for energy continues to increase as the world's population increases. One way to meet these energy demands would be to reduce the use of fossil fuels and obtain energy from other sources.

## section

#### **Summary**

#### **Using Energy**

 Energy cannot be created or destroyed, but can only be transformed from one form to another.

#### **Fossil Fuels**

- Petroleum, natural gas, and coal are fossil fuels formed by the decay of ancient plants and animals.
- Petroleum is a mixture of thousands of chemical compounds, most of which are hydrocarbons.
- About 90 percent of all coal used in the United States is burned by power plants to produce electricity.

#### **Generating Electricity**

 Power plants burn fossil fuels to produce steam that spins turbines attached to electric generators.

#### **Self Check**

- 1. Describe the advantages and disadvantages of using fossil fuels to generate electricity.
- 2. Explain how the different chemical compounds in crude oil are separated.
- 3. Describe how fossil fuels are formed.

review

- 4. Name three materials that are derived from the chemical compounds in petroleum.
- 5. Think Critically If fossil fuels are still forming, why are they considered to be a nonrenewable resource?

#### **Applying Math**

- 6. Interpret a Graph According to the graph in Figure 9, by how many parts per million did the concentration of atmospheric carbon dioxide increase from 1960 to
- 7. Use a Table In Table 1, if the efficiency of converting chemical to thermal energy was 90 percent, what would the overall efficiency be?

# **Nuclear Energy**

## **Reading Guide**

#### What You'll Learn

- Explain how a nuclear reactor converts nuclear energy to thermal energy.
- Describe advantages and disadvantages of using nuclear energy to produce electricity.
- **Discuss** nuclear fusion as a possible energy source.

# Why It's Important

Using nuclear energy to produce electricity can help reduce the use of fossil fuels. However, like all energy sources, the use of nuclear energy has advantages and disadvantages.

#### Review Vocabulary

nuclear fission: the process of splitting an atomic nucleus into two or more nuclei with smaller masses

#### **New Vocabulary**

- nuclear reactor
- nuclear waste

# **Using Nuclear Energy**

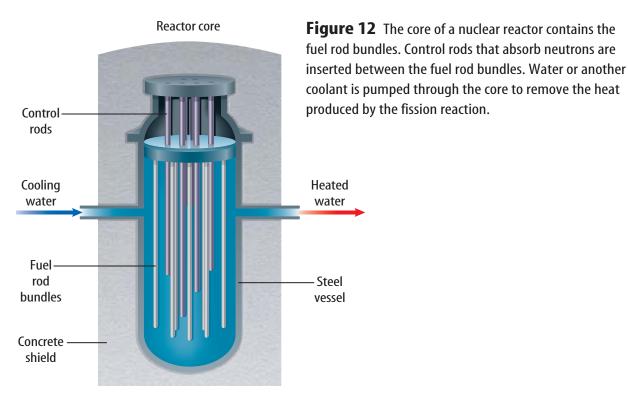
Over the past several decades, electric power plants have been developed that generate electricity without burning fossil fuels. Some of these power plants, such as the one shown in **Figure 11**, convert nuclear energy to electrical energy. Energy is released when the nucleus of an atom breaks apart. In this process, called nuclear fission, an extremely small amount of mass is converted into an enormous amount of energy. Today almost 20 percent of all the electricity produced in the United States comes from nuclear power plants. Overall, nuclear power plants produce about eight percent of all the energy consumed in the United States. In 2003, there were 104 nuclear reactors producing electricity at 65 nuclear power plants in the United States.

Figure 11 A nuclear power plant generates electricity using the energy released in nuclear fission. Each of the domes contain a nuclear reactor. A cooling tower is on the left.



#### **Nuclear Reactors**

A **nuclear reactor** uses the energy from controlled nuclear reactions to generate electricity. Although nuclear reactors vary in design, all have some parts in common, as shown in **Figure 12.** They contain a fuel that can be made to undergo nuclear fission; they contain control rods that are used to control the nuclear reactions; and they have a cooling system that keeps the reactor from being damaged by the heat produced. The actual fission of the radioactive fuel occurs in a relatively small part of the reactor known as the core.



**Nuclear Fuel** Only certain elements have nuclei that can undergo fission. Naturally occurring uranium contains an isotope, U-235, whose nucleus can split apart. As a result, the fuel that is used in a nuclear reactor is usually uranium dioxide. Naturally occurring uranium contains only about 0.7 percent of the U-235 isotope. In a reactor, the uranium usually is enriched

so that it contains three percent to five

percent U-235.

**The Reactor Core** The reactor core contains uranium dioxide fuel in the form of tiny pellets like the ones in **Figure 13.** The pellets are about the size of a pencil eraser and are placed end to end in a tube. The tubes are then bundled and covered with a metal alloy, as shown in **Figure 13.** The core of a typical reactor contains about a hundred thousand kilograms of uranium in hundreds of fuel rods. For every kilogram of uranium that undergoes fission in the core, 1 g of matter is converted into energy. The energy released by this gram of matter is equivalent to the energy released by burning more than 3 million kg of coal.

Figure 13 Nuclear fuel pellets are stacked together to form fuel rods. The fuel rods are bundled together, and the bundle is covered with a metal alloy.

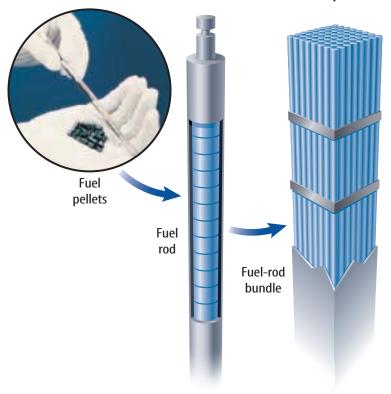
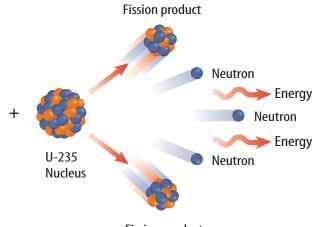


Figure 14 When a neutron strikes the nucleus of a U-235 atom, the nucleus splits apart into two smaller nuclei. In the process two or three neutrons also are emitted. The smaller nuclei are called fission products. **Explain** what happens to the neutrons that are released in this reaction.

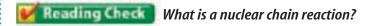


Fission product

**Nuclear Fission** How does the nuclear reaction proceed in the reactor core? Neutrons that are produced by the decay of U-235 nuclei are absorbed by other U-235 nuclei. When a U-235 nucleus absorbs a neutron, it splits into two smaller nuclei and two or three additional neutrons, as shown in **Figure 14.** These neutrons strike other U-235 nuclei, causing them to release two or three more neutrons each when they split apart.

Because every uranium atom that splits apart releases neutrons that cause other uranium atoms to split apart, this process is called a nuclear chain reaction. In the chain reaction involving the fission of uranium nuclei, the number of nuclei that are split can more than double at each stage of the process. As a result, an enormous number of nuclei can be split after only a small number of stages. For example, if the number of nuclei involved doubles at each stage, after only 50 stages more than a quadrillion nuclei might be split.

Nuclear chain reactions take place in a matter of milliseconds. If the process isn't controlled, the chain reaction will release energy explosively rather than releasing energy at a constant rate.



**Controlling the Chain Reaction** To control the chain reaction, some of the neutrons that are released when U-235 splits apart must be prevented from striking other U-235 nuclei. These neutrons are absorbed by rods containing boron or cadmium that are inserted into the reactor core. Moving these control rods deeper into the reactor causes them to absorb more neutrons and slow down the chain reaction. Eventually, only one of the neutrons released in the fission of each of the U-235 nuclei strikes another U-235 nucleus, and energy is released at a constant rate.



#### Uranium-Lead Dating

Uranium is used to determine the age of rocks. As uranium decays into lead at a constant rate, the age of a rock can be found by comparing the amount of uranium to the amount of lead produced. Uraniumlead dating is used by scientists to date rocks as old as 4.6 billion years. Research other methods used to determine the age of rocks.

#### **Nuclear Power Plants**

Nuclear fission reactors produce electricity in much the same way that conventional power plants do. **Figure 15** shows how a nuclear reactor produces electricity. The thermal energy released in nuclear fission is used to heat water and produce steam. This steam then is used to drive a turbine that rotates an electric generator. To transfer thermal energy from the reactor core to heat water and produce steam, the core is immersed in a fluid coolant. The coolant absorbs heat from the core and is pumped through a heat exchanger. There thermal energy is transferred from the coolant and boils water to produce steam. The overall efficiency of nuclear power plants is about 35 percent, similar to that of fossil fuel power plants.

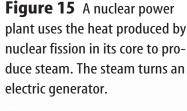
#### **The Risks of Nuclear Power**

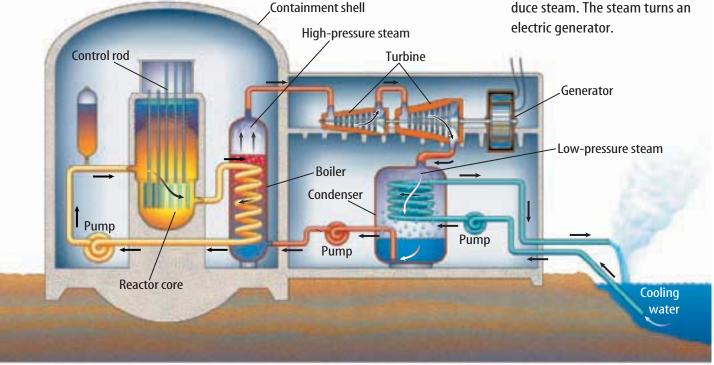
Producing energy from nuclear fission has advantages. Nuclear power plants do not produce the air pollutants that are released by fossil-fuel burning power plants. Also, nuclear power plants don't produce carbon dioxide.

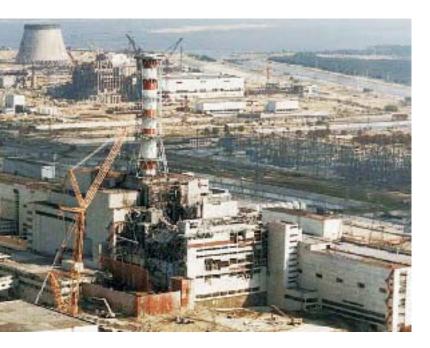
The nuclear generation of electricity also has disadvantages. The mining of the uranium can cause environmental damage. Water that is used as a coolant in the reactor core must cool before it is released into streams and rivers. Otherwise, the excess heat could harm fish and other animals and plants in the water.



Ukraine The worst nuclear accident in history occurred at the Chernobyl nuclear power plant in the Ukraine in 1986. Many people in the area suffered from radiation sickness. Use a map or atlas to find the location of the Ukraine. Write a description of the location in your Science Journal.







**Figure 16** An explosion occurred at the Chernobyl reactor in the Ukraine after graphite control rods caught fire. The explosion shattered the reactor's roof.

The Release of Radioactivity One of the most serious risks of nuclear power is the escape of harmful radiation from power plants. The fuel rods contain radioactive elements with various halflives. Some of these elements could cause damage to living organisms if they were released from the reactor core. Nuclear reactors have elaborate systems of safeguards, strict safety precautions, and highly trained workers in order to prevent accidents. In spite of this, accidents have occurred.

For example, in 1986 in Chernobyl, Ukraine, an accident occurred when a reactor core overheated during a safety test. Materials in the core caught fire and

caused a chemical explosion that blew a hole in the reactor, as shown in **Figure 16.** This resulted in the release of radioactive materials that were carried by winds and deposited over a large area. As a result of the accident, 28 people died of acute radiation sickness. In the United States, power plants are designed to prevent accidents such as the one that occurred at Chernobyl.

# **The Disposal of Nuclear Waste**

After about three years, not enough fissionable U-235 is left in the fuel pellets in the reactor core to sustain the chain reaction. The spent fuel contains radioactive fission products in addition to the remaining uranium. These fuel pellets are a form of nuclear waste. Nuclear waste is any radioactive byproduct that results when radioactive materials are used. Nuclear wastes are classified as low-level waste and high-level waste.

**Low-Level Waste** Low-level nuclear wastes usually contain a small amount of radioactive material. They usually do not contain radioactive materials with long half-lives. Products of some medical and industrial processes are low-level wastes, including items of clothing used in handling radioactive materials. Low-level wastes also include used air filters from nuclear power plants and discarded smoke detectors. Low-level wastes usually are sealed in containers and buried in trenches 30 m deep at special locations. When dilute enough, low-level waste sometimes is released into the air or water.



Visit **gpescience.com** for Web links to information about storing nuclear wastes.

**Activity** Obtain a map or sketch an outline of the United States. Mark the locations of the nuclear waste sites that you found. What do these locations have in common? Why do you think these locations were chosen over other sites that were closer to the nuclear waste generating sites?

**High-Level Waste** High-level nuclear waste is generated in nuclear power plants and by nuclear weapons programs. After spent fuel is removed from a reactor, it is stored in a deep pool of water, as shown in **Figure 17.** Many of the radioactive materials in high-level nuclear waste have short half-lives. However, the spent fuel also contains materials that will remain radioactive for tens of thousands of years. For this reason, the waste must be disposed of in extremely durable and stable containers.

One method proposed for the disposal of highlevel waste is to seal the waste in ceramic glass, which is placed in protective metal-alloy containers. The

containers then are buried hundreds of meters below ground in stable rock formations or salt deposits. It is hoped that this will keep the material from contaminating the environment for thousands of years.



What is the difference between low-level and high-level nuclear wastes?



**Figure 17** Spent nuclear fuel rods are placed underwater after they are removed from the reactor core. The water absorbs the nuclear radiation and prevents it from escaping into the environment.

### **Applying Science**

#### Can a contaminated radioactive site be reclaimed?

n the early 1900s, with the discovery of radium, extensive mining for the element began in the Denver, Colorado, area. Radium is a radioactive element that was used to make watch dials and instrument panels that glowed in the dark. After World War I, the radium industry collapsed. The area was left contaminated with 97,000 tons of radioactive soil and debris containing heavy metals and radium, which is now known to cause cancer. The soil was used as fill, foundation material, left in place, or mishandled.

Radium 88 Ra (226)

#### **Identifying the Problem**

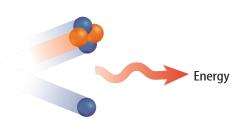
In the 1980s, one area became known as the Denver Radium Superfund Site and was cleaned up by the Environmental Protection Agency. The land then was reclaimed by a local commercial establishment.

#### Solving the Problem

- 1. The contaminated soil was placed in one area and a protective cap was placed over it. This area also was restricted from being used for residential homes. Explain why it is important for the protective cap to be maintained and why homes could not be built in this area.
- 2. The advantages of cleaning up this site are economical, environmental, and social. Give an example of each.

H-3 nucleus

He-4 nucleus



H-2 nucleus

Figure 18 In nuclear fusion, two smaller nuclei join together to form a larger nucleus. Energy is released in the process. In the reaction shown here, two isotopes of hydrogen come together to form a helium nucleus.

**Identify** the source of the energy released in a fusion reaction.

Neutron

dous amount of energy through a process called thermonuclear fusion. Thermonuclear fusion is the joining together of small nuclei at high temperatures, as shown in Figure 18. In this process, a small amount of mass is converted into energy. Fusion

The Sun gives off a tremen-

**Nuclear Fusion** 

is the most concentrated energy source known.

An advantage of producing energy using nuclear fusion is that the process uses hydrogen as fuel. Hydrogen is abundant on Earth. Another advantage is that the product of the reaction is helium. Helium is not radioactive and is chemically nonreactive.

One disadvantage of fusion is that it occurs only at temperatures of millions of degrees Celsius. Research reactors often consume more energy to reach and maintain these temperatures than they produce. Another problem is how to contain a reaction that occurs at such extreme conditions. Until solutions to these and other problems are found, the use of nuclear fusion as an energy source is not practical.

# section

#### review

#### **Summary**

#### **Using Nuclear Energy**

 Nuclear power plants produce about eight percent of the energy used each year in the United States.

#### **Nuclear Power Plants**

- Nuclear reactors use the energy released in the fission of U-235 to produce electricity.
- The energy released in the fission reaction is used to make steam. The steam drives a turbine that rotates an electric generator.

#### The Risks of Nuclear Energy

- Organisms could be damaged if radiation is released from the reactor.
- Nuclear waste is the radioactive by-product produced by using radioactive materials.
- Nuclear power generation produces high-level nuclear wastes.

#### Self Check

- 1. Explain why a chain reaction occurs when uranium-235 undergoes fission.
- 2. Describe how the chain reaction in a nuclear reactor is controlled.
- 3. Compare the advantages and disadvantages of nuclear power plants and those that burn fossil fuels.
- 4. Describe the advantages and disadvantages of using nuclear fusion reactions as a source of energy.
- **5. Think Critically** A research project produced 10 g of nuclear waste with a short half-life. How would you classify this waste, and how would it be disposed of?

#### **Applying Math**

6. Use Percentages Naturally occurring uranium contains 0.72 percent of the isotope uranium-235. What is the mass of uranium-235 in 2,000 kg of naturally-occurring uranium?

# Renewable **Energy Sources**

## **Reading Guide**

## What You'll Learn

- Analyze the need for alternate energy sources.
- Describe alternate methods for generating electricity.
- **Compare** the advantages and disadvantages of various alternate energy sources.

### Why It's Important

Alternative energy sources need to be explored because the primary sources of energy used in the United States are nonrenewable.

#### Review Vocabulary

radiant energy: the energy carried by an electromagnetic wave

#### **New Vocabulary**

- renewable resource
- photovoltaic cell
- hydroelectricity
- geothermal energy
- biomass

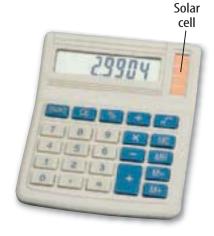
# **Energy Options**

The demand for energy continues to increase, but supplies of fossil fuels are decreasing. Using more nuclear reactors to produce electricity will produce more high-level nuclear waste that has to be disposed of safely. As a result, other sources of energy that can meet Earth's increasing energy demands are being developed. Some alternative energy sources are considered to be renewable resources. A **renewable resource** is an energy source that is replaced nearly as quickly as it is used.

# **Energy from the Sun**

The average amount of solar energy that falls on the United States in one day is more than the total amount of energy used in the United States in one year. Because only about one billionth of the Sun's energy falls on Earth, and because the Sun is expected to continue producing energy for several billion years, solar energy cannot be used up. Solar energy is a renewable resource.

Many devices use solar energy for power including solarpowered calculators similar to the one in **Figure 19.** These devices use a photovoltaic cell that converts radiant energy from the Sun directly into electrical energy. Photovoltaic cells also are called solar cells.



**Figure 19** This calculator uses a solar cell to produce the electricity it needs to operate.

Figure 20 Solar When sunlight strikes a solar cell, electrons cells convert radiant are ejected from the electron-rich semiconductor. These electrons can travel in a energy from the Sun Sunlight closed circuit back to the electron-poor Antireflective to electricity. semiconductor. coating **Identify** two devices Metal contact that use solar cells for Glass cover power. Current A solar cell is made of two layers of semiconductor material.

Electron-poor

semiconductor

Electron-rich

semiconductor



#### **Using Solar Power** at Home

#### Procedure To

- **1.** Complete the safety form.
- 2. Cut a piece of cloth into two pieces about 10 cm on each side.
- 3. Wet both pieces and wring them out so they are equally damp.
- **4.** Spread the pieces out to dry outside. One piece should be in sunlight and the other should be in shade.
- **5.** Record the time it takes for each piece to dry.

#### **Analysis**

- 1. Which piece of cloth received more solar energy?
- 2. Explain why the drying time for a piece of cloth depends on the amount of solar energy it receives.

**How Solar Cells Work** Solar cells are made of two layers of semiconductor materials sandwiched between two layers of conducting metal, as shown in **Figure 20.** One layer of semiconductor is rich in electrons, while the other layer is electron poor. When sunlight strikes the surface of the solar cell, electrons flow through an electrical circuit from the electron-rich semiconductor to the electron-poor material. This process of converting radiant energy from the Sun directly to electrical energy is only about 7 percent to 11 percent efficient.

Metal

contact

Current

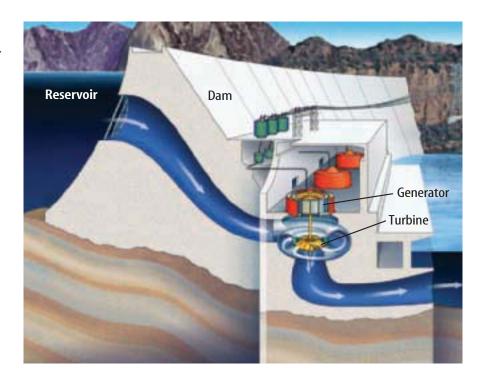
**Using Solar Energy** Producing large amounts of electrical energy using solar cells is more expensive than producing electrical energy using fossil fuels. However, in remote areas where electric distribution lines are not available, the use of solar cells is a practical way of providing electrical power.

Currently, the most promising solar technologies are those that concentrate the solar power into a receiver. One such system is called the parabolic trough. The trough focuses the sunlight on a tube that contains a heat-absorbing fluid such as synthetic oil or liquid salt. The heated fluid is circulated through a boiler where it generates steam to turn a turbine, generating electricity.

The world's largest concentrating solar power plant is located in the Mojave Desert in California. This facility consists of nine units that generate over 350 megawatts of power. These nine units can generate enough electrical power to meet the needs of approximately 500,000 people. These units use natural gas as a backup power source for generating electricity at night and on cloudy days when solar energy is unavailable.

# **Energy from Water**

Just as the expansion of steam can turn an electric generator, rapidly moving water can as well. The gravitational potential energy of the water can be increased if the water is retained by a high dam. This potential energy is released when the water flows through tunnels near the base of the dam. Figure 21 shows how the rushing water spins a turbine, which rotates the shaft of an electric generator to produce electricity. Dams built for this purpose are called hydroelectric dams.



**Using Hydroelectricity** Electricity produced from the energy of moving water is called **hydroelectricity**. Currently about 8 percent of the electrical energy used in the United States is produced by hydroelectric power plants. Hydroelectric power plants are an efficient way to produce electricity with almost no pollution. Because no exchange of heat is involved in producing steam to spin a turbine, hydroelectric power plants are almost twice as efficient as fossil fuel or nuclear power plants.



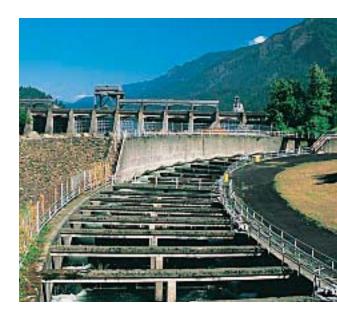
Why are hydroelectric power plants more efficient than fossil fuel power plants?

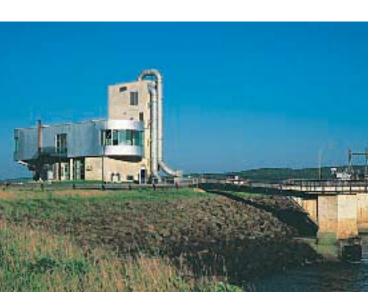
Another advantage is that the bodies of water held back by dams can form lakes that can provide water for drinking and crop irrigation. These lakes also can be used for boating and swimming. Also, after the initial cost of building a dam and a power plant, the electricity is relatively cheap.

However, artificial dams can disturb the balance of natural ecosystems. Some species of fish that live in the ocean migrate back to the rivers in which they were hatched to breed. This migration can be blocked by dams, which causes a decline in the fish population. Fish ladders, such as those shown in **Figure 22**, have been designed to enable fish to migrate upstream past some dams. Also, some water sources suitable for a hydroelectric power plant are located far from the regions needing power.

**Figure 21** The potential energy in water stored behind the dam is converted to electrical energy in a hydroelectric power plant. **Diagram** the energy conversions that occur as a hydroelectric dam produces electrical energy.

**Figure 22** Fish ladders enable fish to migrate upstream past dams.





**Figure 23** This tidal energy plant at Annapolis Royal, Nova Scotia, generates 20 megawatts of electric power.

# **Figure 24** Wind energy is converted to electricity as the spinning propeller turns a generator.

# **Energy from the Tides**

The gravity of the Moon and Sun causes bulges in Earth's oceans. As Earth rotates, the two bulges of ocean water move westward. Each day, the level of the ocean on a coast rises and falls continually. Hydroelectric power can be generated by these ocean tides. As the tide comes in, the moving water spins a turbine that generates electricity. The water is then trapped behind a dam. At low tide the water behind the dam flows back out to the ocean, spinning the turbines and generating electric power.

Tidal energy is nearly pollution free. The efficiency of a tidal power plant is similar to

that of a conventional hydroelectric power plant. However, only a few places on Earth have large enough differences between high and low tides for tidal energy to be a useful energy source. The only tidal power station in use in North America is at Annapolis Royal, Nova Scotia, shown in **Figure 23.** Tidal energy probably will be a limited source of energy in the future.

# **Harnessing the Wind**

You might have seen a windmill on a farm or pictures of windmills in a book. These windmills use the energy of the wind to pump water. Windmills also can use the energy of the wind to generate electricity. Wind spins a propeller that is connected to an electric generator. Windmill farms, like the one shown in **Figure 24,** may contain several hundred windmills.

However, only a few places on Earth consistently have enough wind to rely on wind power to meet energy needs. Also, windmills are only about 20 percent efficient on average. Research is underway to improve the design of wind generators and increase their efficiency. Other disadvantages of wind energy are that windmills can be noisy and change the appearance of a landscape. Also, they can disrupt the migration patterns of some birds. However, wind generators do not consume any nonrenewable natural resources, and they do not pollute the atmosphere or water.

# **Energy from Inside Earth**

Earth is not completely solid. Heat is generated within Earth by the decay of radioac-

tive elements. This heat is called geothermal heat. Geothermal heat causes the rock beneath Earth's crust to soften and melt. This hot molten rock is called magma. The thermal energy that is contained in hot magma is called geothermal energy.

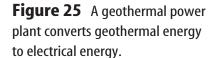
In some places, Earth's crust has cracks or thin spots that allow magma to rise near the surface. Active volcanoes, for example, permit hot gases and magma from deep within Earth to escape. Perhaps you have seen a geyser, like Old Faithful in Yellowstone National Park, shooting steam and hot water. The water that shoots from the geyser is heated by magma close to Earth's surface. In some areas, this hot water can be pumped into houses to provide heat.



What two natural phenomena are caused by aeothermal heat?



**Activity** Using the information that you find, write a paragraph describing why geothermal power plants are located where they are.



#### **Geothermal Power Plants**

Geothermal energy also can be used to generate electricity, as shown in Figure 25. Where magma is close to the surface, the surrounding rocks are also hot. A well is drilled and water is pumped into the ground, where it makes contact with the hot rock and changes into steam. The steam then returns to the surface, where it is used to rotate turbines that spin electric generators.

The efficiency of geothermal power plants is about 16 percent. Although geothermal power plants can release some gases containing sulfur compounds, pumping the water created by the condensed steam back into Earth can help reduce this pollution. However, the use of geothermal energy is limited to areas where magma is relatively close to the surface.

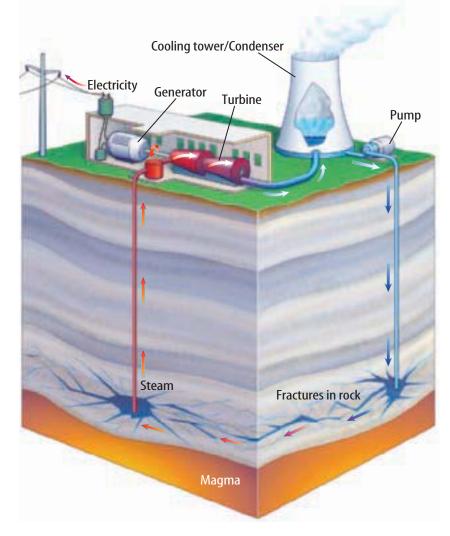




Figure 26 Hydrogen may one day replace gasoline as a fuel for automobiles. Burning hydrogen produces water vapor, instead of carbon dioxide.

#### **Alternative Fuels**

The use of fossil fuels would be greatly reduced if cars could run on other fuels or sources of energy. For example, cars have been developed that use electrical energy supplied by batteries as a power source. Hybrid cars use both electric motors and gasoline engines. Hydrogen gas is another possible alternative fuel. It produces only water vapor when it burns and creates no pollution. Figure 26 shows a car that is equipped to use hydrogen as fuel.

Biomass Fuels Could any other materials be used to heat water and produce electricity like fossil fuels and nuclear fis-

sion? Biomass can be burned in the presence of oxygen to convert the stored chemical energy to thermal energy. Biomass is renewable organic matter, such as wood, sugarcane fibers, rice hulls, and animal manure. Converting biomass is probably the oldest use of natural resources for meeting human energy needs.

#### section гечіеш

#### **Summary**

#### **Energy Options**

 The development of alternative energy sources can help reduce the use of fossil fuels.

#### **Solar Energy**

- Photovoltaic cells, or solar cells, convert radiant energy from the Sun into electrical energy.
- Producing large amounts of energy from solar cells is more expensive than using fossil fuels.

#### **Other Renewable Energy Sources**

- Hydroelectric power plants convert the potential energy in water to electrical energy.
- Tidal energy, wind energy, and geothermal energy can be converted into electrical energy, but are useable only in certain locations.
- Alternative fuels such as hydrogen could be used to power cars, and biomass can be burned to provide heat.

#### **Self Check**

- 1. Explain the need to develop and use alternative energy sources.
- **2. Describe** three ways that solar energy can be used.
- 3. Explain how the generation of electricity by hydroelectric, tidal, and wind sources are similar to each other.
- 4. Explain why geothermal energy is unlikely to become a major energy source.
- 5. Think Critically What single energy source do most energy alternatives depend on, either directly or indirectly?

#### **Applying Math**

**6. Use Percentages** A house uses solar cells that generate 6.0 kW of electrical power to supply some of its energy needs. If the solar panels supply the house with 40 percent of the power it needs, how much power does the house use?



# sigr Heating

Energy from the Sun is absorbed by Earth and makes its temperature warmer. In a similar way, solar energy also is absorbed by solar collectors to heat water and buildings.

# Real-World Problem-

Does the rate at which an object absorbs solar energy depend on the color of the object?

#### Goals

- **Demonstrate** solar heating.
- **Compare** the effectiveness of heating items of different colors.
- **Graph** your results.

#### **Materials**

small cardboard boxes black, white, and colored paper tape or glue thermometer watch with a second hand

## Safety Precautions 📨 🕿 🗫 🕞

### Procedure

- 1. Complete the safety form.
- **2.** Cover at least three small boxes with colored paper. The colors should include black and white as well as at least one other color.
- **3.** Copy the data table into your Science Journal. Replace *Other color* with the color you use.
- **4.** Place the three objects on a windowsill or other sunny spot and note the starting time.
- **5. Measure and record** the temperature inside each box at 2-min intervals for at least 10 min.

Temperature Due to Different Colors					
Color	2 min	4 min	6 min	8 min	10 min
Black					
White	Do n	ot write	in this	book.	
Other color					

# Occiude and Apply

- 1. **Graph** your data using a line graph.
- **2. Describe** the shapes of the lines on your graph. What color heated up the fastest? Which heated up the slowest?
- **3. Explain** why the colored boxes heated at different rates.
- **4. Infer** Suppose you wanted to heat a tub of water using solar energy. Based on the results of this activity, what color would you want the tub to be? Explain.
- **5. Explain** why you might want to wear a white or light-colored shirt on a hot, sunny, summer day.

# Communicating Your Data

Compare your results with those of other students in your class. Discuss any differences found in your graphs, particularly if different colors were used by different groups.



# **Use the Internet**

# How much does energy really co\$t?

#### Goals

- Identify three energy sources that people use.
- Determine the cost of the energy produced by each source.
- Describe the environmental impact of each source.

#### Data Source Internet Lab

Visit gpescience.com for more information about energy sources and for data collected by other students.

### Real-World Problem-

You know that it costs money to produce energy. Using energy also can have an impact on the environment. For example, coal costs less than some other fuels. However, combustion is a chemical reaction that can produce pollutants, and burning coal produces more pollution than burning other fossil fuels, such as natural gas. Even energy sources, such as hydroelectric power, that don't produce pollution can have an impact on the environment. What are some of the environmental impacts of the evergy sources used in the United States? How can these environmental impacts be compared to the cost of the energy produced?

#### Make a Plan

- **1. Research** the various sources of energy used in different areas of the United States and choose three energy sources to investigate.
- **2. Research** the cost of the consumer of 1 kWh of electrical energy generated by energy sources you have choosen.
- **3. Determine** the effects each of the three energy sources has on the environment.



- 4. Use your data to create a table showing the energy sources, and the energy cost and environmental impact of each energy source.
- Decide how you will evaluate the environmental impact of each of your energy sources.
- 6. Write a summary describing which of your three energy sources is the most cost-effective for producing energy. Consider the cost of the energy and your evaluation of the environmental impact in making your decision. Use information from your research to support your conclusions.

# Using Scientific Methods



#### Follow Your Plan

- 1. Make sure your teacher approves your plan before you start.
- **2. Record** your data in your Science Journal.

# Analyze Your Data

- **1.** Of the energy sources you investigated, which is the most expensive to use? The least expensive?
- **2.** Which energy source do you think has the most impact on the environment? The least impact?

Energy Sources		
Energy Source	Cost per kWh	Environmental Impacts
Energy source 1		
Energy source 2	Do not wr	ite in this book.
Energy source 3		

# O Conclude and Apply

- **1. Explain** Of the energy sources you investigated, which is the least expensive energy source? Which is the best choice to use? Why?
- **2. Explain** Of the energy sources you investigated, how did the environmental impact of using that energy source influence your choice of the best energy solution?
- **3. Evaluate** Which data support your decision?

# Communicating Your Data

Find this lab using the link below. Post your data in the table provided. **Compare** your data to those of other students.

Internet Lab gpescience.com

# TIME

# SCIENCE AND SOCIETY

SCIENCE ISSUES THAT AFFECT YOU!

# Reacting to Nuclear Energy

ost people agree that thanks to energy sources, we have many things that make our quality of life better. Energy runs our cars, lights our homes, and powers our appliances. What many people don't agree on is where that energy should come from.

Almost all of the world's electric energy is produced by thermal power plants. Most of these plants burn fossil fuels—such as coal, oil, and natural gas—to produce energy. Nuclear energy is produced by fission, which is the splitting of an atom's nucleus. People in favor of nuclear energy argue that, unlike fossil fuels, nuclear energy is nonpolluting.

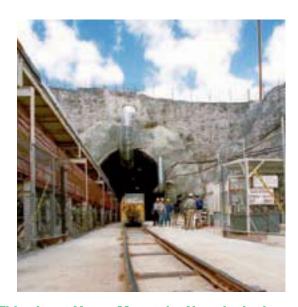
Opponents counter, though, that the poisonous radioactive waste created in nuclear reactors qualifies as pollution—and will be lingering in the ground and water for hundreds of thousands of years.

Supporters of nuclear energy also cite the spectacular efficiency of nuclear energy—one metric ton of nuclear fuel produces the same amount of energy as up to 3 million tons of coal. Opponents point out that uranium is in very short supply and, like fossil fuels, is likely to run out in the next 100 years.

Opponents worry that as utilities come under less government regulation, safety standards will be ignored in the interest of profit.

This could result in more accidents like the one that occurred at Chernobyl in the Ukraine. There, an explosion in the reactor core released radiation over a wide area.

Supporters counter that it will never be in the best interests of those running nuclear plants to relax safety standards since those safety standards are the best safeguard of workers' health. They cite the overall good safety record of nuclear power plants.



This site at Yucca Mountain, Nevada, is the location of a proposed high-level nuclear waste storage facility. Here, radioactive materials would be buried for tens of thousands of years.

**Debate** Form three teams and have each team defend one of the views presented here. If you need more information, go to the link at the right. "Debrief" after the debate. Did the arguments change your understanding of the issues?



# **Reviewing Main Ideas**

#### **Section 1 Fossil Fuels**

- 1. Fossil fuels include oil, natural gas, and coal. They formed from the buried remains of plants and animals.
- 2. Fossil fuels can be burned to supply energy for generating electricity. Petroleum also is used to make plastics and synthetic fabrics.



**3.** Fossil fuels are nonrenewable energy resources. They can be replaced, but it takes millions of years.

#### **Nuclear Energy** Section 2

- **1.** A nuclear reactor transforms the nuclear energy from a controlled nuclear chain reaction into electrical energy.
- 2. Nuclear wastes must be contained and disposed of carefully so radiation from nuclear decay will not leak into the environment. These low-level nuclear wastes are buried to protect living organisms.



**3.** Nuclear fusion releases energy when two nuclei combine. Fusion only occurs at high temperatures that are difficult to produce in a laboratory.

#### Section 3 Renewable Energy Sources

- **1.** Alternative energy resources can be used to supplement or replace nonrenewable energy resources.
- 2. Other sources of energy for generating electricity include hydroelectricity and solar, wind, tidal, and geothermal energy. Each source has its advantages and disadvantages. Also, some of these sources can damage the environment.
- **3.** Although some alternative energy sources produce less pollution than fossil fuels do and are renewable, their use often is limited to the regions where the energy source is available. For example, tides



- can be used to generate electricity in coastal regions only.
- **4.** It may be possible to use hydrogen as a fuel for automobiles and other vehicles. Biomass, such as wood and other renewable organic matter, has been used as fuel for thousands of years.

FOLDABLES Use the Foldable that you made at the beginning of the chapter to help you review energy sources.

#### **Using Vocabulary**

biomass p. 506 fossil fuel p. 487 geothermal energy p. 505 hydroelectricity p. 503 nonrenewable resource p. 493

nuclear reactor p. 494 nuclear waste p. 498 petroleum p. 489 photovoltaic cell p. 501 renewable resource p. 501

Complete each statement using a term from the vocabulary list above.

- **1.** A(n) \_\_\_\_\_ uses the Sun to generate electricity.
- **2.** \_\_\_\_ makes use of thermal energy inside the Earth.
- **3.** Energy produced by the rise and fall of ocean levels is a(n) \_
- \_\_\_\_\_ includes the following: oil, natural gas, and coal.
- **5.** Fossil fuels are a(n) \_\_\_\_\_ because they are being used up faster than they are being made.
- **6.** A special caution should be taken in disposing of \_

#### **Checking Concepts**

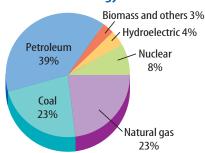
Choose the word or phrase that best answers the question.

- **7.** Why are fossil fuels considered to be nonrenewable resources?
  - **A)** They are no longer being produced.
  - **B)** They are in short supply.
  - **C)** They are not being produced as fast as they're being used.
  - **D)** They contain hydrocarbons.
- **8.** To generate electricity, nuclear power plants produce which of the following?
  - A) steam
- **C)** plutonium
- **B)** carbon dioxide
- **D)** water

- **9.** What is a major disadvantage of using nuclear fusion reactors?
  - **A)** use of hydrogen as fuel
  - **B)** less radioactivity produced
  - c) extremely high temperatures required
  - **D)** use of only small nuclei
- **10.** How are spent nuclear fuel rods usually disposed of?
  - **A)** burying them in a community landfill
  - **B)** storing them in a deep pool of water
  - c) burying them at the reactor site
  - **D)** releasing them into the air

Use the graph below to answer question 11.

#### **Sources of Energy**



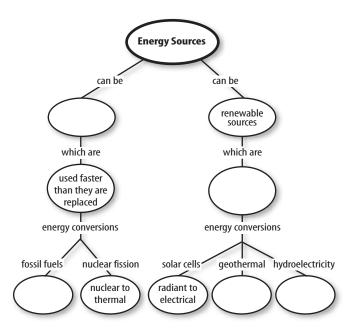
- **11.** How much energy in the United States comes from burning fossil fuels?
  - **A)** 85%
- **c)** 65%
- **B)** 35%
- **D)** 25%
- **12.** What do hydrocarbons react with when fossil fuels are burned?
  - A) carbon dioxide
- **C)** oxygen
- **B)** carbon monoxide **D)** water
- **13.** Which of the following is NOT a source of nuclear waste?
  - A) products of fission reactors
  - **B)** materials with short half-lives
  - c) some medical and industrial products
  - **D)** products of coal-burning power plants
- **14.** Which of the following is the source of almost all of Earth's energy resources?
  - **A)** plants
- C) magma
- **B)** the Sun
- **D)** fossil fuels

#### Interpreting Graphics

**15.** Copy and complete the table below describing possible effects of changes in the normal operation of a nuclear reactor.

Reactor Problems		
Cause	Effect	
The cooling water is released hot.	Do not write in this book.	
The control rods are removed.		
	The reactor core overheats and meltdown occurs.	

**16.** Copy and complete this concept map.



# Thinking Critically

- **17. Infer** why alternative energy resources aren't more widely used.
- **18.** Infer whether fossil fuels should be conserved if renewable energy sources are being developed.

- **19.** Infer Suppose new reserves of fossil fuels were found and a way to burn these fuels was developed that did not release pollutants and carbon dioxide into the atmosphere. Should fossil fuels still be conserved? Explain
- **20.** Explain why coal is considered a nonrenewable energy source, but biomass, such as wood, is considered a renewable energy source.
- **21.** Make a table listing two advantages and two disadvantages for each of the following energy sources: fossil fuels, hydroelectricity, wind turbines, nuclear fission, solar cells, and geothermal energy.

#### **Applying Math**

**22.** Convert Units Crude oil is sold on the world market in units called barrels. A barrel of crude oil contains 42 gallons. If 1 gallon is 3.8 liters, how many liters are there in a barrel of crude oil?

Use the table below to answer question 25.

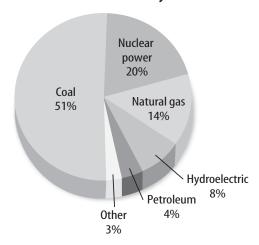
High-Production Coal Mines		
Coal Mine	Metric tons/year	
North Antelope Rochelle	$6.78 \times 10^{7}$	
Black Thunder	$6.13 \times 10^{7}$	

23. Use Percentages Nine of the top coal producing mines are located in Wyoming. Production information on two of the mines is in the table above. A total of about  $1.02 \times 10^9$  metric tons is produced per year in the United States. What percentage do these two coal mines contribute to the total yearly coal production in the U.S.?

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### **Multiple Choice**

# Use the graph below to answer questions 1 and 2. Sources of Electricity



- 1. The graph above shows the percentage of electricity generated in the United States that comes from various energy sources. According to the graph, about what percentage comes from fossil fuels?
  - **A.** 51%
  - **B.** 55%
  - **C.** 65%
  - **D.** 69%
- **2.** The graph shows that approximately what percentage of electricity comes from nonrenewable energy sources?
  - **A.** 97%
  - **B.** 89%
  - **C.** 69%
  - **D.** 55%

- **3.** Which of the following is a typical efficiency for a solar cell?
  - **A.** 10%
  - **B.** 50%
  - **C.** 75%
  - **D.** 95%
- **4.** Which of the following forms only from ancient plant material, not from ancient animal remains?
  - A. coal
  - **B.** crude oil
  - **C.** natural gas
  - **D.** petroleum

#### Use the table below to answer questions 5 and 6.

Efficiency of Fossil-fuel Conversion		
Process	Efficiency (%)	
Chemical to thermal energy	60	
Conversion of water to steam	90	
Steam spins turbine	75	
Turbine spins electric generator	95	
Transmission through power lines	90	

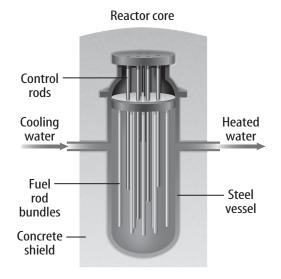
- 5. The table above shows the efficiency of different steps in the conversion of fossil fuels to electricity at a power plant. According to the table, what is the efficiency for converting chemical energy in the fossil fuels to thermal energy, and then converting water to steam?
  - **A.** 40%
  - **B.** 54%
  - **c.** 25%
  - **D.** 90%

#### **Gridded Response**

**6.** What is the overall efficiency shown in the table for converting chemical energy in fossil fuels to electricity?

#### Short Response

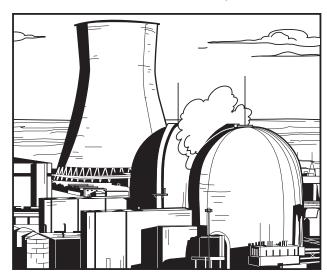
#### Use the illustration below to answer question 7.



- **7.** Describe the purpose of the control rods and explain how their placement in the reactor affects the nuclear chain reaction.
- **8.** Fusion is the most concentrated energy source known. Why, then, is it not used at nuclear plants to make electricity?

#### Extended Response

Use the illustration below to answer question 9.



- **9.** The illustration above shows a nuclear power plant that generates electricity using the energy released in nuclear fission of uranium-235. Draw a sketch showing this fission process. Describe your sketch and explain how the process results in a chain reaction.
- **10.** Describe two advantages and two disadvantages of using fossil fuels as a source of energy.

#### **Test-Taking Tip**

**Determine the Information Needed** Concentrate on what the question is asking about a table, instead of all the information in the table.

Question 5 Read the question carefully to determine which rows in the table contain the information needed to answer the question.

# chapter

# 17

#### BIG (Idea

The uneven heating of Earth's surface causes the movement of air.

#### 17.1 Earth's Atmosphere

MAIN (Idea Water vapor can condense when warm air rises and expands.

#### 17.2 Weather

MAIN (Idea The interaction of warm and cold air masses causes clouds and precipitation.

#### 17.3 Climate

MAIN (Idea Climate is mainly determined by a location's latitude.

# 17.4 Earth's Changing Climate

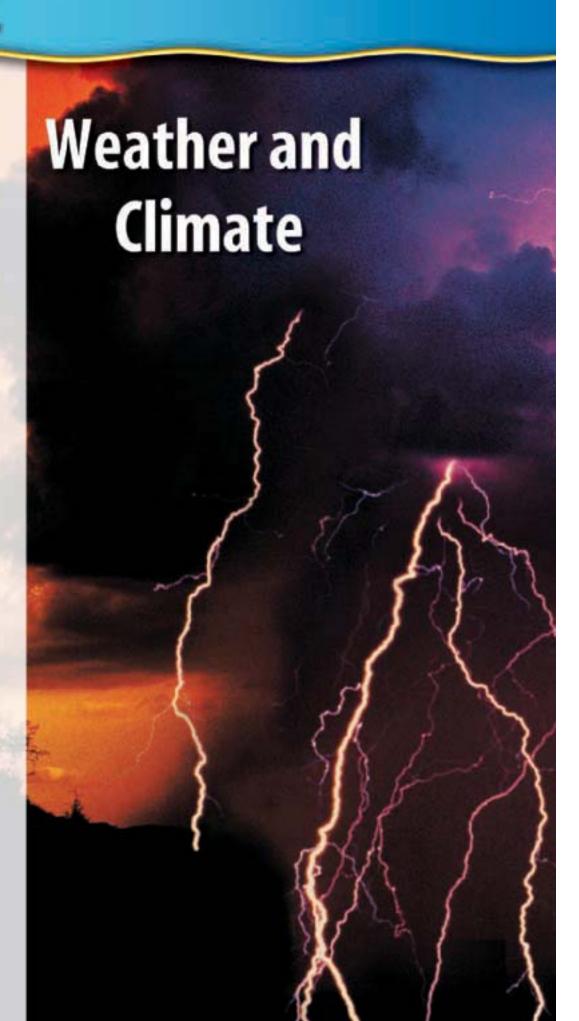
MAIN (Idea Different processes cause climates to change over different time scales.

#### Flash Flood

When cool, dry air meets warm, moist air, dramatic things can happen. In desert environments, flash floods can result when air masses clash. Dry river beds can become raging torrents of water, rocks, and mud.

#### **Science Journal**

In your Science Journal, describe some of your observations of severe weather. Hypothesize what might cause these weather events.



# **Start-Up Activities**



#### **Atmospheric Pressure**

Changes in atmospheric pressure are involved in producing winds and weather. You may not be aware of how much pressure the atmosphere exerts, but you can see it in this Lab.

- **1.** Fill a glass to the brim with water.
- **2.** Place a piece of thick paper or cardboard on top.
- 3. Hold the paper or cardboard securely to the brim of the glass. Turn the glass upside down.
- 4. Release your hand from the paper
- **5. Think Critically** What keeps the paper or cardboard against the brim of the glass and the water from flowing out?



Preview this chapter's content and activities at gpescience.com



Weather and Climate Make the following Foldable to compare and contrast the characteristics of weather and climate.

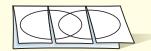
**STEP 1 Fold** one sheet of paper lengthwise.



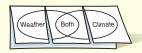
STEP 2 Fold into thirds.



STEP 3 Unfold and draw overlapping ovals.
Cut the top sheet along the folds.



STEP 4 Label the ovals as shown.



Constructing a Venn Diagram As you read the chapter, list the characteristics unique to weather under the left tab, those unique to climate under the right tab, and those elements common to both under the middle tab.

# Earth's Atmosphere

#### **Reading Guide**

#### What You'll Learn

- Describe the composition of the atmosphere.
- **Explain** how the atmosphere is heated and include the role of land surface and water.
- **Describe** Earth's system of water cycling.

#### Why It's Important

Heat and water are essential for life on Farth.

#### Review Vocabulary

nucleus: a central point about which concentration or accretion takes place

#### **New Vocabulary**

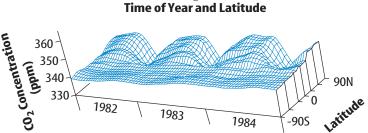
- troposphere
- temperature inversion
- greenhouse effect
- latent heat

#### **Atmospheric Composition**

You probably never think about the air you breathe. Earth's atmosphere is a mixture of gases, including the oxygen your body needs and water vapor. The amount of water vapor in the atmosphere varies from less than 1 percent to about 4 percent, depending on the location and the time. Air that does not include water vapor is called dry air. Dry air contains about 78 percent nitrogen and 21 percent oxygen. Almost all of the remaining 1 percent is argon. Other gases in the atmosphere are called trace gases because they are present in such small amounts. Trace gases include carbon dioxide, which now makes up about 0.04 percent of the atmosphere, neon, methane, nitrous oxide, and ozone.

Reading Check What are the trace gases?

**Figure 1** In northern latitudes, carbon dioxide concentration increases during summer and decreases during winter.



**Biological Processes** Some gases are produced by living organisms. Cellular respiration by organisms produces water vapor and carbon dioxide (CO<sub>2</sub>). Photosynthetic organisms use carbon dioxide and produce almost all the oxygen in the atmosphere. Organisms alter atmospheric CO<sub>2</sub> Comparison of CO<sub>2</sub> Concentration to

concentration at various latitudes throughout the year, as shown in **Figure 1.** Microorganisms in swamps, rice paddies, and soil produce nitrogen and methane. The microorganisms in the digestive tracts of animals such as termites, cows, and sheep produce methane.

**Formation of the Atmosphere** About 4.6 billion years ago, Earth's atmosphere at first was mainly hydrogen and helium. As these gases escaped into space, volcanic eruptions formed an atmosphere made mostly of carbon dioxide and water vapor. Increasing amounts of water vapor resulted in rainfall that slowly formed oceans. Collisions with comets also added water to the atmosphere and the oceans. Carbon dioxide dissolved in the oceans, greatly reducing the amount of carbon dioxide in the air. The evolution of photosynthetic organisms then caused atmospheric oxygen to increase.

High in the atmosphere, some oxygen molecules were converted into ozone molecules by solar radiation, forming the ozone layer. The ozone layer shields Earth from ultraviolet rays that can harm living organisms.

#### **Atmospheric Structure**

Earth's atmosphere extends more than 1,000 km above Earth's surface. Most of our weather takes place within the **troposphere**, a layer extending about 12 km, on average, above Earth's surface. In this layer, as shown in **Figure 2**, temperature normally decreases with height. Sometimes, however, temperature increases with height. This is called a temperature inversion. When this happens, the air is very stable—it resists the rising motion needed to form clouds or to disperse air pollution.

**The Stratosphere** Above the troposphere is the stratosphere, which includes the ozone layer, as shown in Figure 2. Here, temperature always increases with height, creating a permanent

temperature inversion. The place where this temperature inversion begins is called the tropopause. It keeps air in the troposphere from rising into the stratosphere. The uppermost layers, the mesophere and thermosphere, are very low in density and do not affect weather.

**Figure 2** Temperature decreases with height in the troposphere up to the tropopause. Above the tropopause, temperature increases with height in the stratosphere.

**Identify** The ozone layer is found in which atmospheric layer?



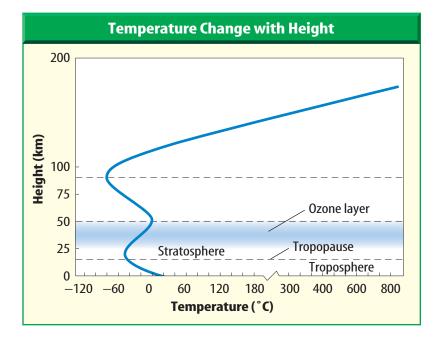
#### Visualizing Convection

#### Procedure

- 1. Place an ice cube in the center of a beaker.
- 2. Add room-temperature water until the beaker is three-fourths full.
- 3. Place one drop of food coloring on the surface of the water.
- 4. Observe what happens.

#### **Analysis**

- 1. Describe what happened to the color.
- 2. Explain why this occurred.



#### **Heating the Atmosphere**

The energy that heats the atmosphere ultimately comes from the Sun. About 30 percent of the solar energy that reaches Earth is reflected back into space by the atmosphere, clouds, and Earth's surface. Another 20 percent is absorbed by the atmosphere. A small fraction of this energy is absorbed by the ozone layer, which warms. This causes temperatures in the stratosphere to increase with height.

About half of the solar energy that strikes the atmosphere passes right through and is absorbed by Earth's surface. This causes Earth's surface to become warmer. As Earth's surface warms, it emits infrared waves back into space. Certain gases, mainly water vapor and carbon dioxide, absorb these infrared waves and become warmer. At the same time, the atmospheric water vapor and carbon dioxide emit infrared waves. Earth's surface absorbs some of these waves and heats up, as shown in **Figure 3.** The emission of infrared waves by gases in Earth's atmosphere is called the **greenhouse effect.** 

Other processes also help heat Earth's atmosphere. Convection transfers thermal energy by movement of air from place to place. The release of latent heat also warms the atmosphere. **Latent heat** is the thermal energy released when water changes state from a gas to a liquid, or from a liquid to a solid. A great deal of thermal energy is released when water vapor condenses and forms clouds.

**Figure 3** Some gases in the atmosphere, such as water vapor and carbon dioxide, absorb infrared waves and are heated. These gases then emit infrared waves in all directions. Some of these infrared waves are absorbed by Earth's surface.

**Infer** How does this compare to being covered by a blanket at night?

# Visible light reflected by clouds Ultraviolet absorbed by ozone Infrared emitted by atmospheric CO<sub>2</sub> and H<sub>2</sub>O Emitted infrared by Earth

#### **A Varied Surface**

As Earth's surface warms, it also heats the air in contact with the surface. However, not all parts of Earth's surface absorb energy and warm in the same way. Surfaces covered by snow, ice, water, vegetation, and bare soil absorb different amounts of energy. Also, different materials warm by different amounts when they absorb energy. For example, water warms much less than other materials as it absorbs energy. This uneven heating of Earth's surface causes differences in pressure and wind.

#### **Water in the Atmosphere**

The uneven heating of Earth's surface produces currents of air that generally rise upward over warm areas. Clouds form when water vapor cools and condenses to form droplets of water. Cloud formation begins as rising air currents carry water vapor upward into the atmosphere. As the air rises, it expands and cools.

For cloud droplets to form, water vapor in the rising air must cool enough for condensation to occur. As the air rises higher, it cools even more. When the air rises high enough, condensation occurs. Then cloud droplets form around small particles of dust and other materials floating in the atmosphere. Cloud droplets are so small that air currents can keep them from falling to Earth.



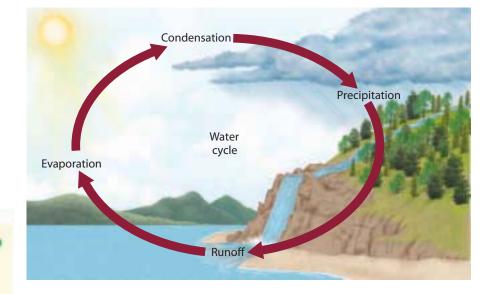
**Types of Clouds** Three basic cloud types are stratus clouds, cumulus clouds, and cirrus clouds. Stratus clouds are layered sheetlike clouds that form at heights below 2,000 m. Stratus clouds often produce long periods of rain. Cumulus clouds are puffy in shape and also usually form below 2,000 m. Under certain conditions, a cumulus cloud can grow upward and become a towering cumulonimbus cloud, or thunderhead. This type of cloud can produce thunderstorms and intense rain. Cirrus clouds form at heights above 6,000 m and are made of ice crystals. **Figure 4** shows the different types of clouds.

**Precipitation** The formation of clouds often results in precipitation. The main types of precipitation are rain, snow, sleet, and hail. For precipitation to occur, cloud droplets must grow larger. Droplets grow larger when they collide and stick together. When they become large enough, they fall to Earth.

**Figure 4** Different types of clouds form at different heights in the atmosphere. Clouds with vertical development grow upward from where they first form.

Cirrus	High Clouds	Height ——— 12 km ————
Cirrocumulus (	Cirrostratus	(about 40,000 ft)
Altocumulus	Middle Clouds (Anvil head) Altostratus	6 km (about 20,000 ft)
Low Clouds	Clouds with vertical development — Cumulonimbus	3 km (about 10,000 ft)
Stratus	Cumulus Cumulus of fair	1.5 km (about 5,000 ft)
Nimbostratus	Stratocumulus weather	(Ground) 0

**Figure 5** In the water cycle, evaporation moves water into the atmosphere, and precipitation returns water back to the land, lakes, and oceans.





**Plants** Transpiration is the loss of water through pores in the leaves of plants. More than 90 percent of the water that enters a plant returns to the atmosphere through the process of transpiration. Research how humidity and air temperature affect transpiration rates in plants. Share your findings with your class.

#### **Global Water Cycle**

Water is always moving between Earth's surface and the atmosphere. This movement of water is called the water cycle, as shown in **Figure 5.** Energy from the Sun evaporates water from Earth's surface. Most evaporation occurs from large bodies of water, such as lakes and oceans. Rising water vapor cools and condenses to form clouds. Condensation results in precipitation that falls over land and water. Some of the water that falls on land evaporates and some runs off into bodies of water. There evaporation also occurs and the cycle continues.

#### section

#### review

#### **Summary**

#### **Atmospheric Structure**

• The stratosphere and the troposphere are two lower layers of Earth's atmosphere. Most weather takes place in the troposphere.

#### **Atmospheric Heating**

- Solar radiation is absorbed and reflected by Earth's surface and the atmosphere.
- The uneven heating of Earth's surface causes the movement of air.

#### Water in the Atmosphere

- Clouds form as water vapor in rising air cools and condenses around small particles.
- Water is always moving between Earth's surface and the atmosphere in the water cycle.

#### Self Check

- 1. **Describe** how temperature of the atmosphere changes with height and explain why.
- 2. Explain the greenhouse effect.
- 3. Explain why Earth's atmosphere today contains more oxygen than Earth's early atmosphere.
- **4. Identify** what must happen before rain can occur.
- **5. Compare and contrast** cumulus and stratus clouds.
- 6. Think Critically How might changes on Earth's surface, such as deforestation, have an effect on weather?

#### **Applying Math**

**7. Use Percentages** If the southern hemisphere contains 10 percent land and the northern hemisphere contains roughly 40 percent land, what percent of Earth is land?



# Visualizing a Temperature Inversion

Normally temperature decreases with increasing altitude in the troposphere. Sometimes near the ground, a temperature inversion occurs and air becomes very stable and resists rising. This can result in fog or smog in cities. Will a liquid behave in the same manner as the atmosphere?

#### Real-World Problem

How can you visualize what happens during a temperature inversion?

#### Goals

- Make a model that demonstrates a temperature inversion.
- **Apply** what you observe to explain what happens in the atmosphere during a temperature inversion.

#### **Materials**

10-mL beaker containing 2—3 mL water
500-mL beaker containing 250 mL water
1,000-mL beaker containing 750 mL water
food coloring ladle
long-stem dropper thermal mitt
freezer hot plate

#### **Safety Precautions**



#### Procedure

**1.** Chill 750 mL of water in a 1,000-mL beaker to near freezing.

- **2.** Add one to two drops of food coloring to the water in the 10-mL beaker and let it stand at room temperature.
- **3.** Heat 250 mL of water in the 500-mL beaker to near boiling.
- 4. Hold the ladle at the surface of the chilled water. Very slowly pour all the heated water into the ladle and allow it to slowly flow out of the ladle onto the surface of the chilled water. You should have a bottom layer of cold water and a top layer of hot water.
- **5.** Use the long-stem dropper to inject a few drops of the colored water from step 2 into the cold water in the 10-mL beaker.

#### Conclude and Apply

- **1. Describe** what happened to the colored water.
- **2. Explain** why this happened in terms of the temperatures of the water layers.
- **3. Infer** how this is related to temperature inversions in the atmosphere.

# Communicating Your Data

Write a brief paragraph describing your experiment and your observations. Include a labeled diagram showing the temperature layers and explain what happened to the colored water.

## Weather

#### **Reading Guide**

#### What You'll Learn

- Explain what causes Earth's major wind and pressure systems.
- Describe typical daily weather patterns around lows and fronts.
- Describe the most important storm systems and forms of severe weather.

#### Why It's Important

Weather affects the health, life, and livelihood of everyone on Earth.

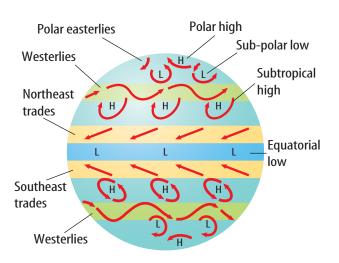
#### Review Vocabulary

**gradient:** the rate of change of a quantity with distance

#### **New Vocabulary**

- westerlies
- jet stream
- subtropical high
- weather front

**Figure 6** In each hemisphere there are four major pressure zones—the equatorial low, the subtropical high, the subpolar low and the polar high. These pressure zones produce the trade winds, the westerlies, and the polar easterlies. **Infer** How does pressure affect wind direction?



#### **Atmospheric Pressure**

The atmosphere exerts a force on any surface in contact with it. This force is equal to the weight of the atmosphere above the surface. The pressure exerted on a surface is the force exerted on the surface divided by the surface area.

When air is heated, it expands and becomes less dense. This means that warmer air weighs less and exerts less pressure than an equal volume of colder air. As a result, the uneven heating of Earth's surface causes differences in air pressure in the atmosphere. These differences in pressure cause air to move. Wind is the movement of air from a region of high pressure to a region of low pressure.

Global Winds and Pressure Systems Large-scale differences in atmospheric pressure cause global wind patterns.

**Figure 6** shows the major zones of high and low pressure and the resulting global winds. The **westerlies**—winds that blow from the west in middle latitudes—and the trade winds, which blow from the east in the tropics, occur in each hemisphere.

Two factors produce these global patterns—unequal heating between the equator and poles and the rotation of Earth. Warm air rising near the equator and sinking over the poles creates general north-south wind circulation. Earth's rotation produces an east-west deflection of this general circulation pattern.

**Jet Streams** Imbedded in these wind systems are fast and powerful jet streams that control many weather processes, such as storm development. Most important for the United States is the polar front jet stream, a wind maximum in the westerlies located about 12 km above the surface. Its speeds can exceed 500 km/h. Major storm tracks follow it as it moves north and south with the seasons.

#### **High and Low Pressure Systems**

A low-pressure system, or low, is a region of the lower troposphere where the air pressure is lower than the air pressure around it. Because air flows from high to low pressure, air flows inward toward a low-pressure system. This inward flow causes the air in the center of the low to rise, as shown in **Figure 7.** As the air in a low rises, it expands and cools, resulting in cloud formation and precipitation. Cloudy weather, rainfall, and storms are associated with lows.

A high-pressure system, or high, is a region of the lower troposphere where the air pressure is higher than the air pressure around it. As a result, air in a high-pressure system flows outward. This outward flow causes the air in the center of a high to sink, as shown in **Figure 7.** Because sinking air does not lead to cloud formation, clear skies and dry weather are associated with highs.

**Coriolis Effect** The direction of airflow is also affected by Earth's rotation. The

effect of Earth's rotation on the motion of objects is called the Coriolis effect. In the northern hemisphere, the Coriolis effect causes winds to be deflected to the right. **Figure 7** shows how the Coriolis effect causes air to flow around highs and lows. Because of the Coriolis effect, in the northern hemisphere air flows counterclockwise around a low and clockwise around a high.



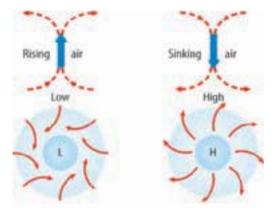
#### **Modeling the Coriolis Effect**

#### **Procedure**

- 1. Put a large, round piece of cardboard or paper on a turnable surface such as a turntable.
- 2. Hold a ruler just above the diameter of the cardboard.
- 3. Ask someone to turn the surface while you draw a line across the turning cardboard with your pen or pencil against the ruler.
- 4. Repeat step 3 but turn the surface in the opposite direction.

#### **Analysis**

- 1. Compare the outlines drawn on the cardboard.
- 2. Explain how these outlines represent the Coriolis effect.



**Figure 7** Air flowing into a low-pressure system rises, while air flowing out of a high-pressure system sinks. In the northern hemisphere, the Coriolis effect causes air to flow counterclockwise around a low and clockwise around a high.

#### **Air Masses and Weather Fronts**

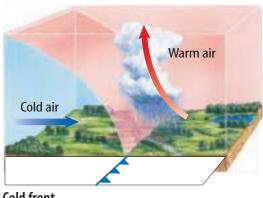
Weather around low-pressure systems is produced by interaction of air masses—large volumes of air with relatively uniform moisture and temperature. These form when air remains stationary for a time, such as in regions of high pressure. The air then takes on the characteristics of the surface. Air masses can be polar or tropical and continental or maritime. Continental air originates over land. It is relatively dry and can be extremely cold or extremely warm. Maritime air masses are moist because they originate over the oceans. The maritime air masses affecting the United States come from the Atlantic Ocean, the Pacific Ocean, or the Gulf of Mexico.

Air masses interact in zones called weather fronts, as shown in **Figure 8**, which are associated with low pressure systems. Warm and cold fronts create different types of precipitation. In a warm front, warm air rises gently above the cold air, usually forming layered, stratus-type clouds or fog—a cloud with its base on the ground. Most layered clouds produce only drizzle or steady rain. In a cold front, cold air pushes the warm air aloft in a random and chaotic fashion forming cumulus clouds. These often produce showers and thunderstorms.

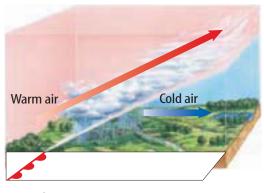
**Figure 8** Weather fronts occur when air masses of different temperatures meet. The symbols shown below each of these weather fronts are used by meteorologists to represent the respective fronts on weather maps.



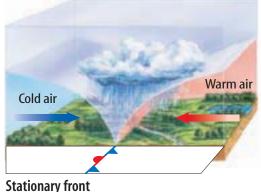
Reading Check What are weather fronts?

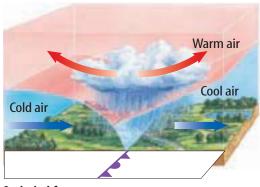


**Cold front** 



Warm front





**Occluded front** 

#### **Severe Weather**

Severe weather often occurs in the continental United States. This is partly due to large temperature differences between warm and cold air masses. Also, nearby tropical oceans provide a source of moisture. Such conditions lead to severe thunderstorms, hurricanes, tornadoes, and violent wind storms called downbursts.

**Thunderstorms** A thunderstorm can form when moist air rises high in the atmosphere. Latent heat is released as the rising air cools and some water vapor condenses. The latent heat released then warms the rising air even more, enabling it to rise even higher. Under some conditions, cumulonimbus clouds can form that produce thunderstorms. In strong thunderstorms these clouds rise as high as 12 km. A typical cumulonimbus cloud, shown in Figure 9, has ice crystals near its top. Water vapor can freeze around these ice crystals. Repeated cycles of sinking and rising can form additional layers of ice. This process produces hailstones that fall to the ground as hail.

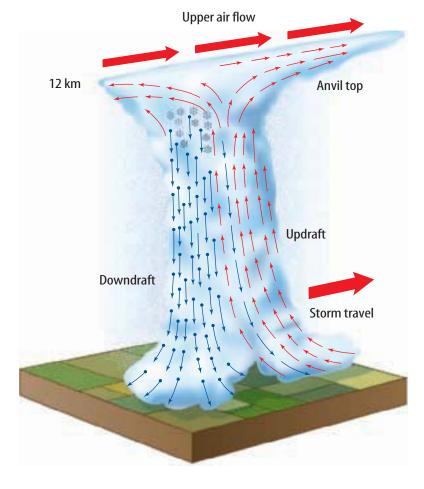
**Downdrafts and Squalls** The falling precipitation in a

thunderstorm cools the air around it and causes cold, dense air to sink to the ground. This sinking current of cold air is called a downdraft. Sometimes when the downdraft hits the ground it spreads out, forming a series of gusty winds called squalls.

**Downbursts** Downdrafts result in a form of severe weather called downbursts. Downbursts occur when cold air descends from a thunderstorm and hits the ground. When it hits the ground, it bursts outward like the spokes on a wheel. The rapid change in wind speed and/or direction that a downburst causes can be dangerous for aircraft during both take-off and landing. The winds that result from downbursts can be as high as 260 km/h. Fortunately, automated warning systems now alert pilots to look for downbursts when signs of approaching an airport.

Figure 9 A tall cumulonimbus cloud produces a thunderstorm. Rising air causes an updraft that helps pull moist air into the cloud. Condensing water vapor releases latent heat, which warms the surrounding air and helps maintain the updraft.

**Infer** Why does this cumulonimbus cloud have an anvil-shaped top?



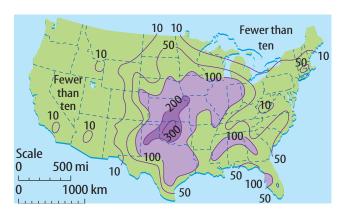


#### **Topic: Hurricane Tracking**

Visit gpescience.com for Web links to information about hurricanes and hurricane tracking.

**Activity** Research six hurricanes. Make a table that lists how each was tracked as a tropical depression and then as a hurricane.

**Figure 10** Texas, Oklahoma, and Kansas frequently experience tornadoes.



**Tornadoes and Hurricanes** Two types of violent wind storms that differ greatly in their origins and effects are tornadoes and hurricanes. Tornadoes are intense, short-lived, localized storms in the mid-latitudes. They originate in cumulonimbus clouds under special conditions. Typically, tornadoes that occur in the United States form when dry air from the deserts of Mexico and the southwest overrides warm, moist air from the Gulf of Mexico. This happens frequently in the Great Plains, the lower midwest, and parts of the south, as shown in **Figure 10.** In the south, they often accompany hurricanes.

A twisting, funnel-shaped tornado cloud can move across land at a speed of around 50 km/h creating a path 150 m wide and 10 km long. Intense, circular winds in the funnel can reach speeds up to 400 km/h. The extreme low pressure at the center can result in more damage than that from the wind.

> Hurricanes are tropical storms that cover vast areas and last for days. Those affecting the United States often form as tropical depressions over the warm waters of the southern Atlantic off the coast of Africa. When winds exceed 118 km/h, the storms are called hurricanes. A typical hurricane consists of vast cloud bands that spiral inward toward the clear center, called the eye. Scientists often fly into the eye to study the storm. Western Pacific hurricanes are called typhoons.

#### section

#### review

#### **Summary**

#### **Global Wind and Pressure Systems**

• Four major pressure systems produce three major wind systems in each hemisphere.

#### **High and Low Pressure Systems**

- Air flows counterclockwise around lows and clockwise around highs in the northern hemisphere.
- Air rises in the center of lows and sinks in the center of highs.

#### **Weather Fronts and Severe Weather**

- Air masses interact at weather fronts.
- Warm fronts are associated with stratus-type clouds and cold fronts with cumulus-type clouds.
- Severe weather includes hurricanes, tornadoes, and downbursts.

#### **Self Check**

- 1. Explain how Earth's rotation affects winds.
- 2. Compare and contrast tornadoes and hurricanes.
- 3. **Describe** the differences in the weather produced by warm fronts and cold fronts.
- 4. **Describe** common differences between continental air masses and maritime air masses.
- **5. Compare and contrast** warm fronts and cold fronts.
- **6. Think Critically** If the polar front jet stream were to move southward over the U.S., what other weather systems are likely to be affected?

#### **Applying Math**

7. Use Percentage A tornado watch was issued on 25 days during one year in a midwest city. What percent of the year does this represent?

# Climate

#### **Reading Guide**

#### *What* You'll Learn

- Describe what determines climate.
- Explain how latitude, oceans, and other factors affect the climate of a region.
- Classify climate systems.
- Describe climate distribution over the United States.

#### Why It's Important

Climate affects the way you live.

#### Review Vocabulary

**boreal:** relating to northern regions

#### **New Vocabulary**

- biosphere
- continental climate
- maritime climate
- lee rain shadow
- sea breeze

#### **Climate and Weather**

What is the climate where you live? Traditionally, climate means the long-term average of weather conditions—wind, temperature, precipitation, moisture, and other aspects of weather. Climate also describes the annual variations of these conditions and their extremes.

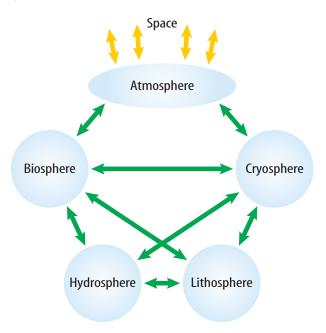
Averages of data collected monthly over 30 years or longer are used to define climatic normals. These normals do not describe usual weather conditions of an area, but are only averages of con-

ditions measured at one local site. For example, the conditions in a city might vary from what is measured at an airport weather station outside the city.

**Climate System** Climate is best considered as part of the whole Earth system. This biogeophysical system can be visualized as five spheres that interact to create the environments in which we live, as shown in **Figure 11.** The atmosphere includes the air around us. The biosphere is all living organisms and the environments in which they live. The hydrosphere is liquid water in oceans, lakes, rivers, soil, and underground. The cryosphere is frozen water in snow, ice, and glaciers. Finally, the lithosphere is the solid Earth, including its soil, rocks, and mantle.

**Figure 11** All of the five spheres shown below interact. Each sphere causes changes in, and is changed by, the others.

**Research** What does the prefix cryo- mean?





#### **Topic: World Climates**

Visit **gpescience.com** for Web links to data on mean annual temperature and rainfall of world cities.

**Activity** Use a world atlas, globe, or large classroom map to find a city corresponding to each of the eight climate divisions shown in **Figure 17**.

**Interactions of Earth Systems** Gases, water-soluble materials, energy, and particulates are exchanged among these spheres. For example, volcanic eruptions transfer gases and particles from the lithosphere to the atmosphere. Water is exchanged between the atmosphere and cryosphere when frozen precipitation falls, melts, and evaporates. Gases, such as nitrogen, oxygen, and carbon dioxide, are exchanged between the atmosphere and the biosphere.

#### What causes climate?

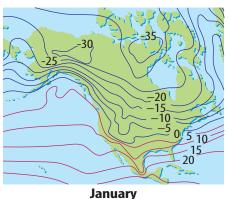
The primary factor that determines the climate at a given location is the location's latitude. Recall that the intensity of the solar radiation received at Earth's surface is greatest at the equator and decreases toward the poles. Also, the direction and strength of the prevailing winds depend on latitude. Other factors include the distances to large bodies of water, such as an ocean, or high mountains. Whether a location is on the east or west side of a continent also affects its climate.

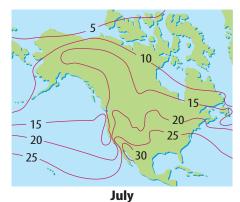
**Differences in Average Temperatures** The long-term average temperature at a given location depends mainly on the location's latitude. Because intensity of solar radiation received at Earth's surface decreases with increasing latitude, average temperatures also decrease with increasing latitude.

However, average summer temperatures do not decrease as much with latitude as average winter temperatures do. In the summer, the number of daylight hours increases from the equator to the poles. The longer period of daylight means that nearly as much solar energy is received during the summer at high latitudes as at lower latitudes. **Figure 12** shows the variations of average temperatures in January and July over North America. Temperature differences between the southern United States and northern Canada are about 55°C in the winter, but only about 25°C in the summer.

**Figure 12** The difference between average temperatures in high latitudes and low latitudes is not as large in summer as in winter. The figure shows isotherms over North America in the winter and the summer. Isotherms are lines that connect points of equal temperature.

**Infer** Why are warmer temperatures shifted northward in July?



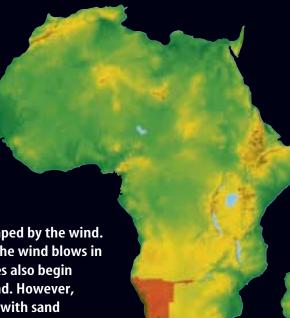


#### NATIONAL GEOGRAPHIC

#### GEOGRAPHIC VISUALIZING EARTH'S BIOGEOPHYSICAL SYSTEM

#### Figure 13

he Namib desert illustrates the interconnectedness of climate, geology, plants, and animals. It is created by high pressure, wind, and cold ocean currents along the west coast of southern Africa.





Transverse dunes form perpendicular to the wind.



Star-shaped dunes form when winds are variable.

The desert is constantly reshaped by the wind. Transverse dunes show that the wind blows in one preferred direction. Dunes also begin when isolated plants trap sand. However, most deserts are not covered with sand dunes—they are made of rocky pavement left behind when wind strips the desert surface. Winds and water remove the finer surface materials, leaving rocks behind. This process is called deflation.

Dense coastal fog forms when the air above cold ocean currents interacts with moist desert air. Although deserts may appear to be dry, the air above the ground contains lots of moisture. Condensation from fog produces fog-water, which drips into desert pavement and dissolves rocks, forming new sediment. It also forms small pools below the rocky surface, which support plant growth. Desert plants have special adaptations such as a dense, compact form and thick, waxy coats. This helps protect them from both heat and animals.



Rock pavement is more common in a desert than dunes.



Beetles capture fog-water by basking upside down or forming trenches at the bottom of dunes. They also survive beneath the leaves of Welwitschia plants where temperatures may be 30°C cooler than the surrounding bare ground.



The Welwitschia plant grows in this barren land by absorbing fog-water through its elongated leaves. It is a relic of millions of years ago and is found only in the Namib.

Ocean and Land Influence Oceans and ocean currents also affect climate. A climate that is strongly affected by an ocean is called a maritime climate. A climate that is not directly affected by an ocean is called a **continental climate**. Maritime climates are milder—summers are cooler, winters are warmer, and daily temperatures vary less. Peoria, Illinois, and San Francisco, California, are at the same latitude—40°N. However, Peoria has a continental climate and San Francisco has a maritime climate. The temperature difference between the warmest and coldest months is about 8° C in San Francisco and 30° C in Peoria. Maritime effects are strong enough to keep winters at arctic Spitsbergen, Norway at 78° N latitude, warmer than in International Falls, Minnesota at 48° N latitude.

**Precipitation** Wind and pressure patterns determine precipitation. Humid climates are associated with low-pressure areas in the tropics and the middle latitudes. Rainfall is greater near the equator because the trade winds of both hemispheres converge there, increasing the rising motion. Dry climates are associated with high-pressure regions. Climates tend to be even drier in the subtropics on the eastern sides of the subtropical highs.

Superimposed upon this general pattern are differences related to location on a continent, as shown for North America in **Figure 14.** The west coast lies east of the subtropical high, which brings cold water currents and stable air. This creates the dry climates of California and the southwest. The east coast lies west of the subtropical high, where southerly winds bring warm, unstable air from the Gulf of Mexico that increases precipitation. Air masses can also influence the amount of precipitation an area receives. When continental polar air masses, which originate in

0

Centimeters above 500 500 200 100 100 50 50 30 of Can¢er 10

the cold, dry arctic regions, move across the Midwestern states in the winter, cold, dry weather results.

Another factor affecting precipitation is the prevailing winds. Because winds blow from the west in the middle latitudes, the maritime influence is stronger on the west coast. This explains why San Francisco has a strongly developed maritime climate, but Boston has a continental climate.

**Figure 14** Average precipitation over North America tends to be greater over coastal regions. Lines connecting points of equal precipitation are called isohyets. **Research** What does the prefix iso- mean?

100



**Influence of Mountains** Mountains can affect precipitation patterns. The presence of a mountain range causes air masses to rise as they approach the mountains. The rising air cools and precipitation occurs on the windward side of the mountains, as shown in **Figure 15.** As a result, the air mass is drier when it sinks down the leeward side of the mountains. Less rain occurs on the leeward side of a mountain range, an effect called the lee rain shadow. The Great Plains lie in the lee rain shadow of the Rocky Mountains.

**Influence of Water** Coasts and lakeshores can affect regional climates. In winter, lake-effect snow often occurs around the Great Lakes, as shown in Figure 16. As cold, continental air from the north passes over warmer lake water, the air mass gains heat and moisture. When the air mass reaches the colder land to the south or east of a lake, heavy snowfall occurs.

Sea breezes are also caused by the influence of water. A sea breeze blows from the water toward the land in the afternoon, when the land is warmer than the water. Warm air rises over the land creating low pressure that allows cool, dense air to blow from the sea toward land. The reverse happens at night when the land is cooler than the water. A land breeze occurs when cool, dense air over land creates high pressure causing the air to blow from the land toward the sea.

**Climate Scale** Many small-scale variations also occur within the large-scale climate patterns. Some are regional or local and others, termed microclimates, are variations within small distances. For example, cities tend to be warmer than surrounding areas—a condition called the heat island effect. Building and pavement materials heat up more rapidly than land. On some clear, calm nights, downtown San Francisco can be as much as 8°C warmer than the surrounding rural areas.

**Figure 15** Air on the windward side of a mountain rises and cools, resulting in precipitation. The climate on the windward side of a mountain tends to be cool and wet. The air on the leeward side of the mountain is drier and warms as it sinks. The climate on the leeward side is often hot and dry.

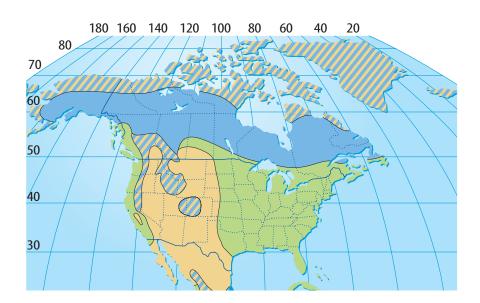
Figure 16 Lake-effect snow occurs in areas east and south of the Great Lakes. These areas are shaded in purple in the figure below.



Cold Arid	tundra
Cold	boreal
Dry winter	evergreen forest
Warm Arid	desert
Warm Semi-arid	grassland
Wet winter	Mediterranean
Dry summer	forest
Wet summer	temperate
Dry winter	woodland
Warm	subtropical
Wet	deciduous forest
Warm	tropical
Wet	deciduous forest

Figure 17 Climate zone influences the types of vegetation that will grow there.

**Infer** What are two major factors that characterize climate types?



#### **Types of Climates**

Geographer Glenn Trewartha and meteorologist Lyle Horn designed a system to classify climates, shown in **Figure 17.** It has three major divisions—cold or boreal, arid and semi-arid, and climates with adequate heat and precipitation. The last includes temperate, subtropical, and tropical climates. These divisions are closely correlated with vegetation.

#### section

#### review

#### **Summary**

#### Climate and Weather

 Climate is the net result of interactions involving all aspects of the biogeophysical system called Earth.

#### What causes climate?

- The main causes of climate are the distribution of solar radiation and the location of pressure and wind systems.
- Oceans, land masses, mountains, and large lakes also affect climate.
- Climates are classified on the basis of temperature and moisture availability.
- Prevailing high pressure or the rain shadow of mountains can produce dry climates.

#### **Types of climate**

Climates can be classified into three major divisions.

#### Self Check

- 1. Explain why a climatic normal does not tell you exactly what weather to expect where you live.
- **2. Identify** the five elements of the biogeophysical system called Earth.
- **3. Explain** the association between climate and latitude.
- 4. Compare and contrast continental and maritime climates.
- 5. Think Critically Would you expect the daily temperature range to be greater in a maritime climate or a continental climate? Explain.

#### **Applying Math**

6. Calculate Range The coolest average summer temperature in the United States is 2°C at Barrow, Alaska, and the warmest is 37°C at Death Valley, California. Calculate the range of average summer temperatures in the United States.



# **Earth's Changing Climates**

#### **Reading Guide**

#### **What** You'll Learn

- Explain how climate changes seasonally.
- **Explain** causes of climate change.
- **Describe** how we influence climate.
- **Explain** El Niño's effect on weather.

#### Why It's Important

Changing climates affect all life on Earth.

#### Review Vocabulary

**trace:** a minute, barely detectable amount present

#### **New Vocabulary**

- global warming
- El Niño
- La Niña

#### **Seasonal Changes**

Seasonal changes occur as Earth orbits the Sun. The hemisphere tilted toward the Sun experiences summer while the hemisphere tilted away from the Sun experiences winter. During the summer, a hemisphere receives more intense solar radiation and temperatures rise. During winter, the intensity of solar radiation decreases and temperatures drop. Seasonal changes are smallest near the equator and become greater with increasing latitude.

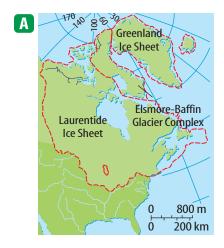
#### **Long-term Changes**

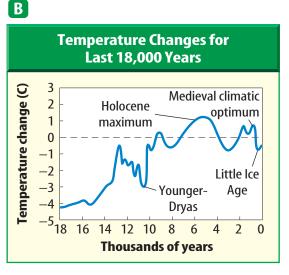
Over the past few million years, large ice sheets have formed and then melted a number of times. The period when large ice sheets cover much of Earth's surface is called an ice age. The last ice age began about 100,000 years ago and ended about 10,000

years ago. **Figure 18A** shows that at the peak of the last ice age, about 18,000–22,000 years ago, ice sheets covered much of North America.

However, by about 5,000 years ago, the ice sheets had almost completely melted. Global climate patterns began to change into what they are today. Since then, other climate changes have occurred. **Figure 18B** shows temperature variations in the northern hemisphere over the past 18,000 years. A warm period from the eleventh to the fourteenth centuries, called the medieval climatic optimum, enabled the Vikings to colonize Greenland. This was followed by a cooler period called the Little Ice Age that lasted from about the seventeenth century to the middle of the nineteenth century.

**Figure 18** At the peak of the last ice age, about 18,000 years ago, thick ice sheets covered much of North America.







#### Dinosaur Extinction

The impact of a large asteroid 65 million years ago on Mexico's Yucatán peninsula may have caused the extinction of dinosaurs and other species. The dust from such an impact would have caused months of darkness and drastically lowered temperatures. Animals like dinosaurs that needed large supplies of food would have suffered most. Research what evidence scientists have for such an impact and report your findings to your class.

**Causes of Climate Change** There are a number of factors that cause climate change. These factors affect climate over different time scales. For example, over millions of years, plate movements and uplift are important. Over decades and years, changes in ocean currents and snow and ice cover can be important.

Periodic changes in Earth's orbit around the Sun change the amount and distribution of solar radiation that reaches Earth. Earth's orbit changes shape slightly with a period of about 100,000 years. Also, Earth's rotation axis wobbles with a period of about 23,000 years. This changes the time of year when Earth is closest and farthest from the Sun. Finally, the tilt of Earth's rotation axis varies between 21.5° and 24.5°, with a period of 41,000 years. Currently the tilt is about 23.5°.

The amount of energy emitted by the Sun also changes. For example, from about 1645 to 1715, almost no sunspots were seen on the Sun. This meant that solar activity was low, and the amount of solar radiation emitted by the Sun was reduced. During this time period, extreme cold temperatures and long winters occurred in Europe.

Volcanoes can affect climate over a period of a few years. Large eruptions can produce droplets of sulfuric acid in the stratosphere that reflect incoming solar radiation. This reduces the amount of solar energy reaching Earth's surface. The eruption of Mt. Tambora in Indonesia in 1815 resulted in unusually cold weather in 1816, which was known as the year without a summer.

#### **The Human Factor**

Human activities, such as the burning of fossil fuels, manufacturing processes, deforestation, draining of wetlands, and intensive agriculture, have affected Earth's atmosphere. These activities modify the surface heating and the water and carbon cycles. They also affect the composition of the atmosphere.

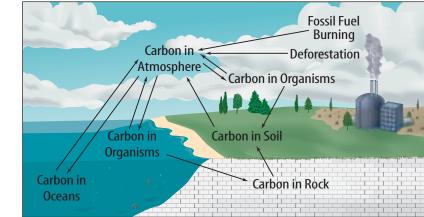


Figure 19 When organisms die and decay, some carbon is stored as humus in the soil and some is released back to the atmosphere as carbon dioxide.

**Describe** how trees affect levels of carbon dioxide and oxygen in the atmosphere.

The Carbon Cycle In the carbon cycle, shown in Figure 19, carbon is exchanged among the ocean, the land and the atmosphere. The concentration of atmospheric carbon dioxide can be affected by changes in the carbon cycle. For example, deforestation and loss of vegetation affect atmospheric carbon dioxide in two ways. One is that less carbon dioxide is absorbed from the atmosphere by photosynthesis. The other is that the decaying and burning wood produced by deforestation adds carbon dioxide to the atmosphere.

#### Applying Math

#### **Calculate**

**CARBON DIOXIDE (CO<sub>2</sub>) CONCENTRATION** Concentration of  $CO_2$  in the atmosphere has increased at a constant rate of about 4.2 percent per decade over at least the last 30 years. Assuming this rate remains constant, you can predict its concentration in the future by using the following formula:

$$CO_2$$
 (year + 10) =  $CO_2$  (year) +  $CO_2$  (year) × rate of  $CO_2$  increase

#### **IDENTIFY** known values and unknown values

#### Identify the known values:

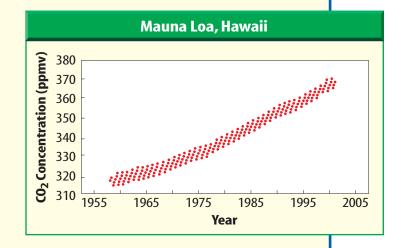
The concentration of CO<sub>2</sub> in 2000 was 369 ppm

Rate of CO<sub>2</sub> increase between 1990 and 2000 was 4.2 percent

#### Identify the unknown value:

What will be the concentration of carbon dioxide in 2010?

Concentration of  $CO_2 = ? ppm$ 



#### SOLVE the problem

Substitute the known values into the equation:

Concentration in  $2010 = 369 \text{ ppm} + 369 \times 0.042$ 

Concentration in 2010 = 384.5

#### **CHECK** your answer

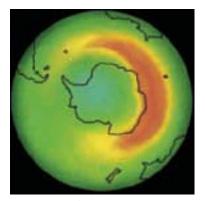
Multiply  $369 \times .042$  and subtract from 384.5 to get the value in 2000.

#### **Practice Problems**

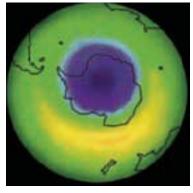
- 1. Use the same method to find carbon dioxide concentration in 2020.
- 2. Assuming that conservation efforts reduce the rate of carbon dioxide increase to 2.6 percent per decade, predict the concentration in 2010.

For more practice problems, go to page 879 and visit Math Practice at gpescience.com.

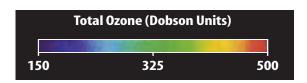
**Figure 20** The concentration of springtime ozone over Antarctica has decreased over the past several decades. Shown are springtime Antarctic ozone concentrations in 1979 and 2003, measured in Dobson Units. In 2003, springtime ozone amounts are less than half of the 1979 values.



Oct. 1979



Oct. 2003



**Greenhouse Gases** Water vapor and carbon dioxide are examples of greenhouse gases. These gases produce the greenhouse effect by absorbing energy emitted by Earth and emitting energy back to Earth's surface. Since 1850, the concentration of atmospheric carbon dioxide has increased by about 30 percent. This increase is mainly due to human activities—mainly the burning of fossil fuels and land-use changes. Human activities have also increased the atmospheric concentration of other greenhouse gases, including methane and nitrous oxide.

**Changes in Land Use** About one-third of the increase in atmospheric carbon dioxide is due to land-use changes. One type of land-use change is deforestation to produce farm land. Deforestation involves the clearing of trees from large areas of forest. Trees remove carbon dioxide from the atmosphere as photosynthesis occurs. As a result, reducing the number of trees reduces the rate at which carbon dioxide is removed from the atmosphere in the carbon cycle. This increases the amount of atmospheric carbon dioxide.

**Global Warming** An increase in the concentration of atmospheric greenhouse gases could increase the greenhouse effect and raise surface temperatures. In fact, temperature data show that since 1906, Earth's average surface temperature has increased by about 0.7°C. An increase in the average global temperature is called **global warming.** Some of this change is due to the increase in greenhouse gases, mainly carbon dioxide, that result from human activity. According to some estimates, doubling the concentration of atmospheric carbon dioxide could cause the average surface temperature to increase by 3°C. Such an increase could have significant effects on precipitation patterns and global sea level.

**The Antarctic Ozone Hole** Over Antarctica an annual seasonal reduction occurs in atmospheric ozone. Every year as winter ends, ozone amounts in the ozone layer begin to decrease. Ozone levels reach a minimum in October, and then increase again to their winter values. During the past few decades, October ozone levels have dropped significantly, as shown in **Figure 20.** This decrease in springtime Antarctic ozone levels is called the ozone hole. The ozone hole is caused by synthetic

> chemical compounds called chlorofluorocarbons (CFCs) in the atmosphere. CFCs are used in refrigerators, air conditioners, and aerosol sprays. To prevent damage to the ozone layer, the production and use of CFCs is being phased out.

#### El Niño and La Niña

El Niño is the warming of the Pacific Ocean off the coast of western South America that occurs every 3 to 10 years. Normally, trade winds push warm surface water westward in the Pacific Ocean. Off the western coast of South America, warm surface water is replaced by cold, nutrient-rich water that rises from below the surface. When the trade winds weaken, warm surface water is no longer pushed westward. The upwelling of the cold, nutrient-rich water stops and the surface water remains warm.

Fewer fish and other marine life can be supported by the nutrient-poor warm water. Rainfall in the western Pacific decreases, where as heavy rain and flooding can occur on the normally dry coast of Peru. El Niño can dramatically alter global weather patterns. For example, a strong El Niño can lead to flooding and mudslides in California, as shown in Figure 21, and droughts in India, Australia, and parts of Africa.

The opposite of El Niño is La Niña, which occurs when tradewinds in the Pacific are unusually strong and equatorial oceanic surface temperatures are colder than normal. La Niña can cause drought in the southern United States and excess rainfall in the northwest.



Figure 21 Parts of the Pacific Coast Highway in California have been disrupted by erosion and mudslides caused by El Niño.

#### section review

#### **Summary**

#### **Seasonal Changes**

• The tilt of Earth's axis changes the amount of solar radiation received by the northern and southern hemispheres throughout the year, causing the seasons.

#### **Long-Term Climate Changes**

- Climate can change over time scales ranging from millions of years to several years.
- Plate movement, orbital changes, solar activity, and volcanoes can cause climate changes.

#### The Human Factor

 Human activities have increased the amounts of atmospheric greenhouse gases and have affected the ozone layer over Antarctica.

#### El Niño and La Niña

 El Niño is a warming in the Pacific Ocean that has global effects. La Niña is a cooling of the equatorial Pacific Ocean.

#### **Self Check**

- 1. **Identify** ways that humans may be affecting climate.
- 2. Explain why some volcanic eruptions can cause climate to change.
- 3. Explain why it is difficult to identify any single cause of an observed climate change.
- 4. Think Critically What could cause climate changes that occur on a time scale of 50,000 years?

#### **Applying Math**

- 5. Use Percentages The eruption of Mount Pinatubo in 1991 put large amounts of dust into the atmosphere. Scientists say this decreased the average global temperature about 0.8 percent during the next year. How would this affect an area with an average temperature of 25°C before the eruption?
- **6. Calculate** Areas of the southeastern United States may receive 15 percent of their rain during hurricanes. If average rainfall for this area ranges from 100-200 cm, how much of this might be from hurricanes?



#### **Design Your Own**

#### **Investigating Microclimate**

#### Goals

Investigate how environmental variables respond to various microclimates.

#### **Possible Materials**

directional compass thermometer rain gauge meter stick small plastic cups \*graduated cylinder \*Alternate materials

#### **Safety Precautions**

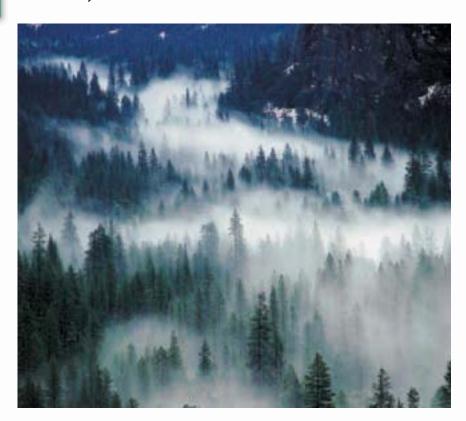


#### Real World Problem

While we can talk about global climate or regional climate, we also can discuss climate on the scale of a few meters. We call climate at this scale a microclimate. For example, because cold, heavy air flows downhill, valley fog sometimes forms in moist, low-lying areas. Along the California coast, coastal fog collects on the needles of redwood trees, drips to the ground, and is absorbed by the tree's shallow root system. This microclimate helps the coastal redwoods survive, nestled in the fog belt along the California coast. In this lab, you will investigate local differences in microclimate.

#### Form a Hypothesis

Choose an aspect of climate, such as precipitation, light, or temperature. Form a hypothesis to explain how this aspect influences local environments. Predict how these factors will vary in response to differences in your microclimate variable.



#### Using Scientific Methods

#### Test Your Hypothesis

#### Make a Plan

- 1. Decide what microclimate factor you will investigate, and what environmental factor you will monitor for effects.
- **2.** How will you measure the selected microclimate variable? What equipment will you need? How often will you make measurements?
- **3.** Choose sites for making measurements. Will these sites vary in microclimate? Is the environmental variable you chose present in these places?
- **4.** Decide how you will measure your environmental variable. What equipment will you need? How often will you make measurements? Should the microclimate measurements happen at the same time?
- **5.** Prepare a data table to record your measurements. Will you record the time of the measurements? Should you record the weather at the time of measurements?
- **6.** Before you begin, list the steps of your procedure. Include all materials needed for each step. Does your procedure give you the data necessary to test your hypothesis?

#### **Follow Your Plan**

- **1.** Be sure that your teacher approves your plan before you start.
- **2.** Carry out your experiment as planned. Be sure to record all data in the appropriate places. Follow all appropriate safety precautions.
- **3.** Record all observations and data in your Science Journal.

#### Analyze Your Data-

- **1. Make a graph** of your data. Put the microclimate variable on the *y*-axis, and the environmental variable on the *x*-axis.
- **2. Discuss** any trends you see in the data based on your graph.
- **3. Infer** any effects that the weather had on microclimate variables. How did this affect your environmental variable?

#### Conclude and Apply

- 1. Discuss your predicted environmental response to microclimate. Did your results support your hypothesis?
- **2. Predict** how changes in global climate would affect the microclimate and response variables that you studied.



**Compare** your results with the data of other students who measured the same microclimate variable. Present the combined data to the class. For more help, refer to the Science Skills Handbook.



# Science Language TIS

### The Grapes of Wrath

by John Steinbeck



In *The Grapes of Wrath*, Steinbeck tells the story of the fictional Joad family, who lived in Oklahoma in the 1930s. Like thousands of families living in the drought-stricken dust bowl of the central United States, the

Joads were tenant farmers who lost their farm. Such families piled their belongings into rickety trucks and migrated to California seeking work as fruit pickers.

Although the drought alone caused much hardship, it was gigantic dust storms that finally destroyed their crops. Steinbeck describes such a storm in the following words:

"The wind grew stronger, whisked under stones, carried up straws and old leaves, and even little clods, marking its course as it sailed across the fields. The air and the sky darkened and through them the sun shone redly, and there was a raw sting in the air. During a night the wind raced faster over the land, dug cunningly among the rootlets of the corn, and the corn fought the wind with its weakened leaves until the roots were freed by the prying wind and then each stalk settled wearily sideways toward the earth and pointed the direction of the wind."

When the storm finally ended, the buildings, fences, and trees were blanketed with thick layers of dust—a grim reminder of how the Joads' lives had been changed forever.

#### Understanding Literature

**Historical Novels** Authors often use historical events as inspiration. When a piece of fiction combines historical events or characters with fictional plot and dialogue, it becomes a historical novel. Well-writtenhistorical fiction can aid the reader in understanding how people actually experienced an important time in history.

#### Respond to the Reading

- 1. How does the dust storm affect the crops?
- **2.** What might cause such a dust storm?
- Linking Science and Reading Write a paragraph describing the effects of a hurricane or tornado.



The dust bowl resulted from inter-

actions between natural elements, such as climate, plants, and soil, and human elements, such as farming practices and economics. When the dust bowl occurred, vegetation was already sparse. This reduced friction and allowed the wind to gain speed. With no moisture to bind soil particles together, the soil eroded. Dust from these storms was carried up to 3,000 km away from its original source. The dust storms were a type of squall that sometimes bring rain to these semi-arid plains.

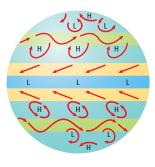
#### **Reviewing Main Ideas**

#### **Section 1 Earth's Atmosphere**

- **1.** Earth's atmosphere is 78 percent nitrogen, 21 percent oxygen, one percent argon, and includes small amounts of trace gases.
- 2. The stratosphere is the upper layer of the atmosphere where temperature always increases with height. The troposphere is the lower layer where most weather occurs.
- **3.** The troposphere is heated primarily by Earth's surface after it absorbs radiation. from the Sun.
- 4. Land absorbs and emits heat efficiently, but water resists temperature change.
- **5.** Clouds form when warm air carrying water vapor rises until it is cool enough to condense.

#### **Section 2** Weather

1. Major pressure belts and wind belts are caused by unequal heating between the equator and the poles and modifications resulting from Earth's rotation.



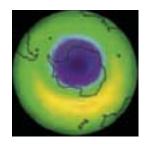
- 2. Specific weather patterns are associated with high and low pressure cells.
- 3. Air masses are large blocks of air with similar properties of moisture and temperature throughout. They interact in zones called weather fronts.
- **4.** Severe weather includes thunderstorms. downbursts, tornadoes, and hurricanes.

#### Section 3 **Climate**

- 1. Climate refers to the mean weather conditions and their annual variations in an area.
- **2.** Climate is part of an Earth system that includes the atmosphere, biosphere, hydrosphere, cryosphere, and lithosphere.
- **3.** Latitude is the most important factor in determining climate.
- 4. Continents, mountains, and oceans influence climate on a large scale, and smallscale variations are termed microclimates.

#### **Section 4 Earth's Changing Climates**

- **1.** Long-term changes include cycles of glaciation. Causes of climate change include plate motion, changes in Earth's orbit, solar activity, and volcanism.
- 2. Human activities have increased the concentration of carbon dioxide and other greenhouse gases in the atmosphere.
- **3.** Global surface temperature data show that since 1906, Earth's average surface temperature has increased by 0.7°C.
- 4. El Niño and La Niña affect ocean currents and coastal winds, causing serious droughts and flooding in some areas.



FOLDABLES Use the Foldable that you made at the beginning of this chapter to review what you have learned about weather and climate.

#### **Using Vocabulary**

biosphere p. 529 continental climate p. 532 El Niño p. 539 global warming p. 538 greenhouse effect p. 520 jet stream p. 525 La Niña p. 539 latent heat p. 520 lee rain shadow p. 533

maritime climate p. 532 sea breeze p. 533 subtropical high p. 525 temperature inversion p. 519 troposphere p. 519 weather front p. 526 westerlies p. 524

*Match the correct vocabulary word(s) with each* definition given below.

- **1.** area of interaction between air masses
- 2. climate with a strong ocean influence
- **3.** energy used to evaporate water
- **4.** layer of the atmosphere where most weather occurs
- **5.** global weather event(s) that involve oceans and the atmosphere
- **6.** most important of three major wind belts
- 7. fast, powerful air current that affects many weather processes
- **8.** area of reduced precipitation on one side of a mountain range
- **9.** a region of very stable air that resists rising needed to form clouds and dispel pollution
- **10.** warming of the atmosphere due to energy absorption by certain gases

#### **Checking Concepts**

Choose the word or phrase that best answers the question.

- **11.** Which has great ranges in temperature and little ocean influence?
  - A) continental climate
  - B) El Niño
  - C) La Niña
  - **D)** maritime climate

- **12.** Which describes the deflection of wind currents due to Earth's rotation?
  - A) trade winds
  - **B)** Coriolis effect
  - **c)** greenhouse effect
  - **D)** urban heat island
- **13.** Which is the most important factor in determining climate at a given location?
  - **A)** altitude
- **c)** latitude
- **B)** continents
- **D)** mountains

Use the illustration below to answer question 14.



- **14.** Which influence on regional climate is shown above?
  - **A)** continental location
  - **B)** lake effect
  - () lee rain shadow
  - **D)** maritime location
- **15.** Which triggers droplet formation in clouds?
  - **A)** evaporation
- **C)** ozone
- **B)** particles
- **D)** thermals
- **16.** What type of weather is most closely associated with a warm front?
  - A) drizzle or steady rain
  - **B)** downbursts or windshear
  - **c)** hurricanes or tornadoes
  - **D)** thunderstorms
- **17.** Which is a greenhouse gas?
  - A) argon
- **C)** oxygen
- **B)** nitrogen
- **D)** water vapor
- **18.** A heat island is an example of which type of climate?
  - A) tropical climate C) microclimate
  - **B)** boreal climate
- **D)** dry climate

#### **Interpreting Graphics**

- **19. Illustrate** Earth's major pressure belts and wind belts, with labels showing the westerlies and the trade winds.
- **20.** Make a table comparing characteristics of continental and maritime climates.

Use the data in the following table to answer question 21.

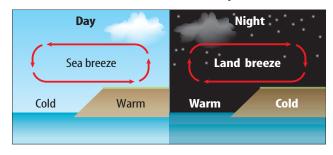
City Temperatures				
Cities at Degrees N Latitude	Average July Temperature (°C)	Average January Temperature (°C)		
72	20	<b>-45</b>		
41	21	9		
45	29	-2		
40	31	<b>—10</b>		

**21. Identify** Based on the data in the table above, identify the latitudes of the cities that have maritime and continental climates.

#### **Thinking Critically**

- **22.** Explain why the continental United States is prone to severe weather, such as tornadoes and hurricanes.
- **23.** Explain why the release of latent heat enables an air mass to rise higher in a cumulonimbus cloud.
- **24.** Form a hypothesis about how we might determine whether human activities have played a role in global warming.
- **25. Describe** how the composition of Earth's atmosphere would be different than it is today if organisms in which photosynthesis occurs had never evolved.

Use the illustration below to answer question 26.



- **26.** Explain why a sea breeze blows toward the land in the afternoon, and a land breeze blows toward the water in the evening.
- **27. Predict** how a large forest fire might affect the formation of clouds over regions around the forest fire.
- **28.** Explain why the uneven heating of Earth's surface causes differences in air pressure.
- **29. Explain** how water droplets form in clouds and the conditions needed to make them fall as some form of precipitation.
- **30.** Explain why the increase of temperature with height in the stratosphere prevents tropospheric air from rising into the stratosphere.
- **31. Explain** how El Niño affects global weather patterns.

#### **Applying Math**

- **32.** Convert Units The high temperature of a summer day in the United States might be 81°F. What would this temperature be in France where they use Celsius temperatures? Hint: Use the formula  $^{\circ}C = (^{\circ}F - 32) \times 5/9.$
- **33.** Compare Ratios City A had 175 cloudy days in 2004. In 2004, 56 percent of city B's days were cloudy. Which city had more cloudy days? Show the calculations you did to find your answer.

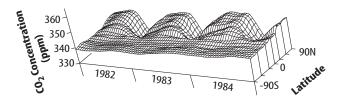
Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### Multiple Choice

- **1.** Which makes up most of Earth's atmosphere?
  - A. carbon dioxide
  - **B.** carbon monoxide
  - **C.** nitrogen
  - D. oxygen

#### Use the figure below to answer question 2.

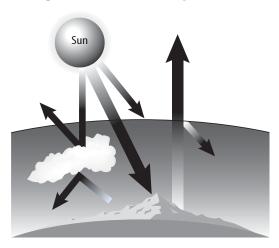
Comparison of CO<sub>2</sub> Concentration to Time of Year and Latitude



- 2. What causes the seasonal changes in atmospheric carbon dioxide in the northern hemisphere?
  - **A.** El Niño events
  - **B.** photosynthetic organisms
  - **c.** weather fronts
  - **D.** greenhouse effect
- **3.** Which accumulated in the stratosphere over millions of years and shielded Earth from ultraviolet rays from the Sun?
  - **A.** argon
  - B. nitrogen
  - **C.** oxygen
  - D. ozone

- **4.** Which type of air mass would most likely be moist and warm?
  - A. continental polar
  - **B.** continental tropical
  - **C.** maritime polar
  - **D.** maritime tropical
- **5.** Which is a series of windy gusts formed when a downdraft hits Earth's surface with particularly strong force?
  - A. hail
  - **B.** squall
  - **c.** thunderstorm
  - **D.** tornado

Use the diagram below to answer guestion 6.



- **6.** Which is caused by absorption of infrared waves by some atmospheric gases?
  - A. condensation
  - **B.** greenhouse effect
  - **C.** latent heat
  - **D.** precipitation

#### Use the table below to answer question 7.

Land Surface	Percent Reflected Solar Radiation
Bare soil	25
Snow	90
Desert	50
Dense forest	10

- 7. Over which surface is the least amount of solar radiation absorbed?
  - **A.** bare soil
  - **B.** dense forest
  - **C.** desert
  - D. snow
- **8.** Which are fast, powerful flows of wind imbedded in global wind systems?
  - **A.** jet streams
  - **B.** sea breezes
  - **C.** subtropical highs
  - **D.** westerlies

#### **Gridded Response**

**9.** If the average concentration of carbon dioxide in Earth's atmosphere at the beginning of the nineteenth century was 280 ppm and it presently is 380 ppm, what percentage of today's concentration existed at the beginning of the nineteenth century?

#### Test-Taking Tip

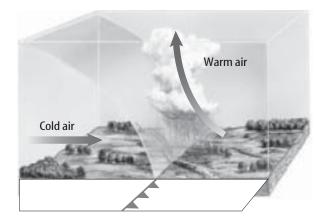
Review Never leave any answer blank.

#### Short Response

- **10.** In the southern hemisphere, the Coriolis effect deflects air currents to the left, instead of to the right. Infer the direction of rotation of air around a high-pressure system in the southern hemisphere.
- **11.** Describe what happens to a mass of air as it rises in the atmosphere.
- **12.** What causes uneven patterns of heating on Earth's surface?
- 13. Which factors cause climate?

#### **Extended Response**

#### Use diagram below to answer question 14.



**14. PART A** What are weather fronts? PART B How do air masses interact at a cold front?



# **Matter and Earth Materials**

от стема эл
ПЕРИОДИЧЕСКАЯ СИ СТЕМА — ПЕРИОДИ — ПЕРИОДИ СТЕМА — ПЕРИОДИ —
ПЕРИОДИЧЕСКАЯ ОТЕНТОВ
T V V V
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H 1 JUWAJE
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1 29096 140.00 1 A A A A A A A A A A A A A A A A A A
4 29 Cu 30 Zn ; 78,96 ; 78,96 ; 78,96 ; 78,96
4 Y 65.38 65.38 69.72 72.60 74.91 Mo 42 Ma 43
27 C- 38 Y 39 Zr 1 05.95 1 - 1
W RD 1 88.92 1 91.22 1 52 Tb 53
85,48 1 10,50 SN 3 SD 1 126,92
1 A A Q 4 Ca 4 118,70 1 121,76 1 75
YII 107,88 1 112,41 1 57 LIE 72 Ta 73 1 W
Cc 35   Ba 36   La *   180,88   183,92   186,31
YIII 13738 1138,92 1 68 Ri 1: POH -
6 129 And 80 HQ 10 11 11 11 200 00 1 210 1
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JAHTAHH ADA
60 ; 61 ; Sm 62 ; Eu
150,43 1152,0
14427 : Tu 69 ! Yb
HO 1 169.4 173,0
164,94 ; 167.2
548





are inserted into glass tubes to be used in art and signage.

#### chapter



#### BIG (Idea

Matter can be classified by what it is made of, by its physical properties, and by its chemical properties.

#### 18.1 Composition of Matter

MAIN (Idea Matter can be either a pure substance (an element or a compound) or a mixture (either heterogeneous or homogeneous).

#### **18.2 Properties of Matter**

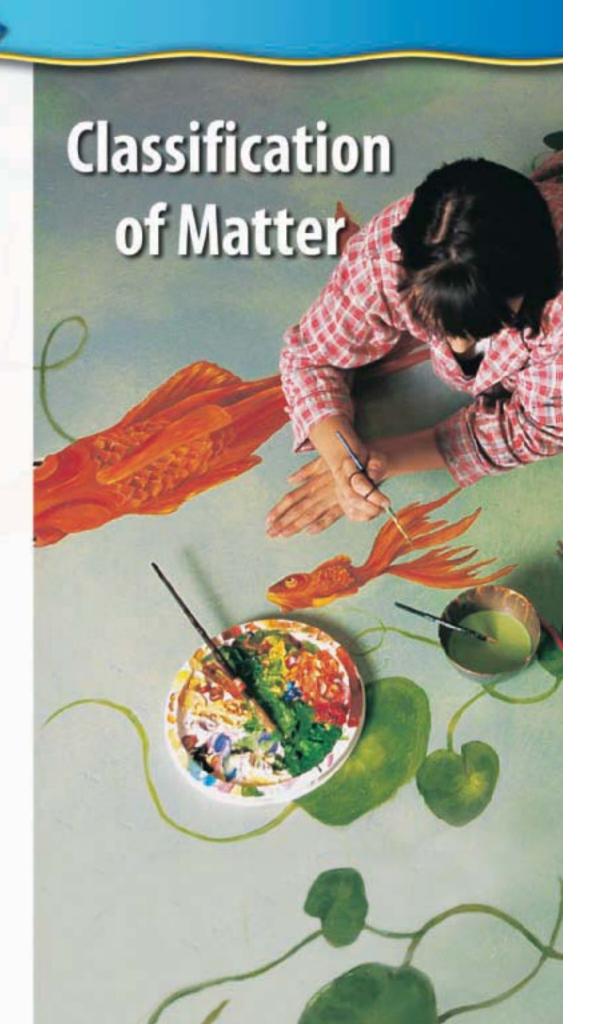
MAIN (Idea A physical property can be observed without changing the identity of the material. A chemical property describes whether it can undergo a chemical change.

#### The Art of Mixtures

When painting, colors can be skillfully mixed to achieve a certain shade, or the artist can show several individual pigments in a single brush stroke. Paint undergoes physical and chemical changes with time that can make the artist's work endure.

#### **Science Journal**

Describe the changes that take place as the paint dries, particularly which changes are physical and which are chemical.



#### **Start-Up Activities**



#### Demonstrate the Distillation of Water

Matter is classified according to the different properties that it exhibits. These differences in properties allow drinking water to be obtained from seawater. These properties could be very important to you if you were stranded on a desert island and needed drinking water. Purified water can be obtained through a process called distillation.





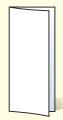
- 1. Complete the safety form.
- Place 75 mL of water in a 200-mL beaker and add 20 drops of blue food coloring.
- 3. Place the beaker on a hot plate.
- **4.** Add ice to an evaporating dish until the dish is half full. Place the evaporating dish on the beaker as shown in the photo.
- **5.** Turn on the hot plate and slowly bring the water and food-coloring solution to a boil.
- 6. After boiling the solution for five minutes, carefully remove the evaporating dish using heat-resistant gloves. Touch the drops of liquid on the bottom of the dish to a piece of white paper.
- **7.** Observe the liquid on the paper.
- **8. Think Critically** In your Science Journal, write a paragraph explaining where the liquid came from. What was in the beaker that is not in the liquid on the paper?



Classification of Matter Make the following Foldable to understand the content by

ensure that you understand the content by defining the vocabulary terms from this chapter.

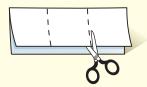
Fold a sheet of paper vertically from side to side. Make the front edge about 1.25 cm shorter than the back edge.



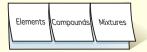
Turn lengthwise, with the fold on top, and fold into thirds.



STEP 3 Unfold and cut only the top layer along both folds to make three tabs.



STEP 4 Label the tabs *Elements, Compounds,* and *Mixtures* as shown.



**Define** As you read the chapter, define each term and list examples of each under the appropriate tab.



Preview this chapter's content and activities at gpescience.com

# **Composition of Matter**

#### **Reading Guide**

#### What You'll Learn

- Define substances and mixtures.
- Identify elements and compounds.
- Compare and contrast solutions, colloids, and suspensions.

#### Why It's Important

You will have a better knowledge of your world when you understand the concepts of elements and compounds.

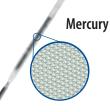
#### Review Vocabulary

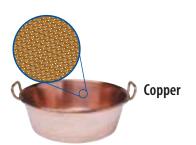
property: characteristic or essential quality

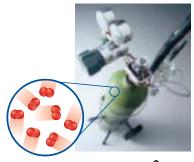
#### New Vocabulary

- substance
- element
- compound
- heterogeneous mixture
- homogeneous mixture
- solution
- colloid
- Tyndall effect
- suspension

**Figure 1** All the atoms of an element are alike.







**Oxygen** 

#### **Pure Substances**

Have you ever seen a photo hanging on a wall that looked just like a real painting? Did you have to touch it to find out? If so, the rough or smooth surface told you whether it was a painting or a photo. Every material has its own properties. The properties of materials can be used to classify them into general categories.

Every material is made of a pure substance or a mixture of substances. A pure substance is a type of matter with a fixed composition. A substance can be either an element or a compound. Some substances you might recognize are helium, aluminum, water, and salt.

**Elements** All substances are built from atoms. If all the atoms in a substance have the same identity, that substance is an **element.** The graphite in your pencil point and the copper coating of most pennies are examples of elements. In graphite, all a atoms are carbon atoms, and in a copper sample, all the atoms are copper atoms. The metal substance beneath the copper in a penny is another element—zinc. About 90 elements are found on Earth. More than 20 others have been made in laboratories, but most of these are unstable and exist only for short periods of time. Some elements you might recognize are shown in **Figure 1.** Some less-common elements and their properties are shown in **Figure 2.** 

#### **NATIONAL** GEOGRAPHIC VISUALIZING ELEMENTS

#### Figure 2

ost of us think of gold as a shiny yellow metal used to make jewelry. However, it is also an element that is used in more unexpected ways, such as in spacecraft parts. On the other hand, some less-common elements, such as americium (am uh REE see um), are used in everyday objects. Some elements and their uses are shown here.



TITANIUM (tie TAY nee um) Parts of the exterior of the Guggenheim Museum in Bilbao, Spain, are made of titanium panels. Strong and lightweight, titanium is also used for body implants.



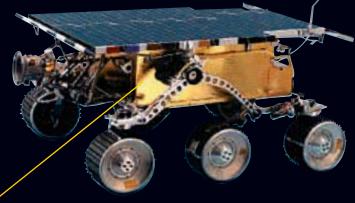
**LEAD** Because lead has a high density, it is a good barrier to radiation. Dentists drape lead aprons on patients before taking X rays of the patient's teeth to reduce radiation exposure.



**ALUMINUM Aluminum** is an excellent reflector of heat. Here, an aluminum plastic laminate is used to retain the body heat of a newborn baby.



▲ TUNGSTEN Although tungsten can be combined with steel to form a very durable metal, in its pure form it is soft enough to be stretched to form the filament of a lightbulb. Tungsten has the highest melting point of any metal.



**GOLD** Gold's resistance to corrosion and its ability to reflect infrared radiation make it an excellent coating for space vehicles. The electronic box on the six-wheel Sojourner Rover, above, part of NASA's Pathfinder 1997 mission to Mars, is coated with gold.



**■** AMERICIUM Named after America, where it was first produced, americium is a component of this smoke detector. It is a radioactive metal that must be handled with care to avoid contact.

**Compounds** When two or more different elements combine, the substance formed is called a compound. A **compound** is a pure substance in which the atoms of two or more elements are combined in a fixed proportion. For example, water is a compound in which two atoms of the element hydrogen combine with one atom of the element oxygen. Chalk contains calcium, carbon, and oxygen in the proportion of one atom each of calcium and carbon to three atoms of oxygen.





Can you imagine yourself putting something made from a silvery metal and a greenish-yellow, poisonous gas on your food? You might have shaken some on your food today—table salt is a chemical compound that fits this description. Even though it looks like white crystals and adds flavor to food, its components—sodium and chlorine—are neither white nor salty, as shown in **Figure 3.** Like salt, other compounds usually look different from the elements in them.

Figure 3 Chlorine gas and sodium metal combine dramatically in the ratio of one to one to form sodium chloride.

**Molecules** A particle consisting of two or more atoms that are bonded together is called a molecule. Oxygen in the air, as an example, is a diatomic (two-atom) molecule. A molecule is a basic unit of a molecular compound. The simple sugars you eat; the proteins in your body; and the wool and cotton fibers in your clothes all consist of molecules formed from bonded atoms.

**Figure 4** The number of mixtures that can be created by combining substances is unlimited.



# **Mixtures**

Are pizza and a soft drink one of your favorite lunches? If so, you enjoy two foods that are classified as mixtures, but two different kinds of mixtures. A mixture, such as the pizza or soft drink shown in Figure 4, is a material made up of two or more substances that can be easily separated by physical means.

**Heterogeneous Mixtures** Unlike compounds, mixtures do not always contain the same proportions of the substances that make them up. For example, a pizza chef doesn't measure precisely how much of each topping is sprinkled on a pizza. You easily can see most of the toppings on a pizza. A mixture in which different materials can be distinguished easily is called a **heterogeneous** (he tuh ruh JEE nee us) **mixture**. Granite, concrete, and dry soup mixes are other heterogeneous mixtures you can recognize.

You might be wearing another heterogeneous mixture—clothing made of a permanent-press fabric like the one shown in **Figure 5A.** Such a fabric contains fibers of two materials—polyester and cotton. The amounts of polyester and cotton can vary from one article of clothing to another, as shown by the label. Though you might not be able to distinguish the two fibers just by looking at them, you probably could if you used a microscope, as shown in **Figure 5B.** 

Most of the substances you come in contact with every day are heterogeneous mixtures. Some components are easy to see, such as the ingredients in pizza, but others are not. In fact, a component you see can be a mixture itself. For example, the cheese in pizza is also a mixture, but you cannot see the individual components. Cheese contains many compounds, such as milk proteins, butterfat, colorings, and other food additives.



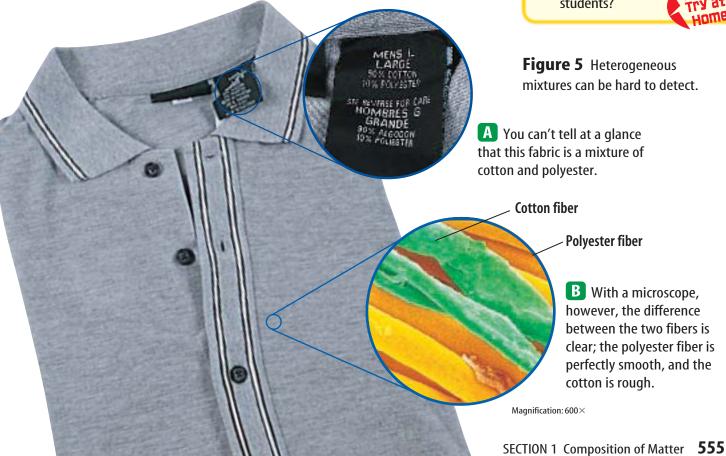
#### **Classifying Materials**

#### **Procedure**

- 1. In your Science Journal, create a data table with four columns and 11 rows. Label the columns Elements, Compounds, Mixtures, and Explanation.
- 2. Choose ten items in your home and classify each as an element, a compound, or a mixture. List them in your table in the appropriate columns.
- **3.** In the *Explanation* column, explain why you classified the items as you did.

#### **Analysis**

- 1. How many elements did you find?
- 2. Which column has the greatest number of items? Is this the same for all students?



**Homogeneous Mixtures** Remember that soft drink you like with your pizza? Some soft drinks contain water, sugar, flavoring, coloring, and carbon-dioxide gas.

Soft drinks in sealed bottles are examples of homogeneous mixtures. A **homogeneous** (hoh muh JEE nee us) **mixture** contains two or more gaseous, liquid, or solid substances blended evenly throughout. However, a soft drink in which you can see bubbles of carbon-dioxide gas and ice cubes is a heterogeneous mixture.

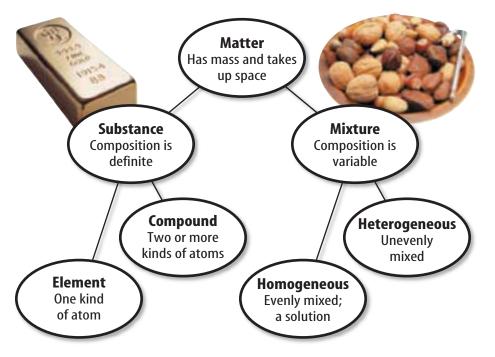
Vinegar is another homogeneous mixture. It appears to be clear, even though it is made up of particles of acetic acid mixed with water. Another name for a homogeneous mixture such as vinegar and a bottled soft drink is a solution. A **solution** is a homogeneous mixture of particles so small that they cannot be seen with a microscope and will never settle to the bottom of their container. Solutions remain constantly and uniformly mixed. The differences between substances and mixtures are summarized in **Figure 6.** 

**Reading Check** What kind of mixture is a solution?

**Colloids** Milk is an example of a specific kind of mixture called a colloid. Like a heterogeneous mixture, milk contains water, fats, and proteins in varying proportions. Like a solution, its components won't settle when it is left standing. A **colloid** (KAH loyd) is a type of mixture with particles that are larger than those in solutions but not heavy enough to settle out. The word *colloid* comes from a Greek word for *glue*. The first col-

loids studied were in gelatin, a source of some types of glue.

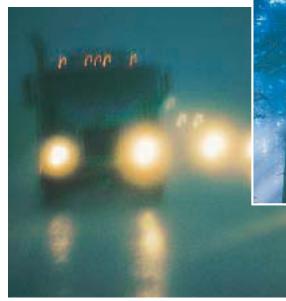
Paint is an example of a liquid with suspended colloid particles. Gases and solids can contain colloidal particles, too. For example, fog consists of particles of liquid water suspended in air, and smoke contains solids suspended in air.



**Figure 6** All matter can be divided into substances and mixtures.

**Figure 7** Fog is a colloid composed of water droplets suspended in air.

The light from the headlights is scattered by the fog.



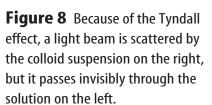
The same colloid allows you to see the sunlight as it streams through the trees.

**Detecting Colloids** One way to distinguish a colloid from a solution is by its appearance. Fog appears white because its particles are large enough to scatter light as shown in Figure 7. Sometimes it is not so obvious that a liquid is a colloid. For example, some shampoos and gelatins are colloids called gels that appear almost clear. You can tell for certain if a liquid is a colloid by passing a beam of light through it, as shown in **Figure 8.** A light beam cannot be seen as it passes through a solution, but can be seen readily as it passes through a colloid. This occurs because the particles in the colloid are large enough to scatter light, but those in the solution are not. This scattering of light by colloidal particles is called the **Tyndall effect**.



How can you distinguish a colloid from a solution?







## **Topic: John Tyndall**

Visit **gpescience.com** for Web links to information about the discoverer of the Tyndall effect.

**Activity** Prepare a book cover describing the various activities of John Tyndall.



**Figure 9** The mud deposited by the Mississippi River is thought to be more than 10,000 m thick. **Calculate** in kilometers how thick the mud in the Mississippi River is.

# Table 1 Comparing Solutions, Colloids, and Suspensions

Description	Solutions	Colloids	Suspensions
Settle upon standing?	no	no	yes
Separate using filter paper?	no	no	yes
Particle size	0.1–1 nm	1–1,000 nm	>1,000 nm
Scatter light?	no	yes	yes

**Suspensions** Some mixtures are neither solutions nor colloids. One example is muddy pond water. If pond water stands long enough, some mud particles will fall to the bottom, and the water clears. Pond water is a suspension, which is a heterogeneous mixture containing a liquid in which visible particles settle. **Table 1** summarizes the properties of different types of mixtures.

River deltas are large scale examples of how a suspension settles. Rivers flow swiftly through narrow channels, picking up soil and debris along the way. As a river widens, it flows more slowly. Suspended particles settle and form a delta at the mouth, as shown in **Figure 9.** 

# section

## гечіеш

#### **Summary**

#### **Pure Substances**

- An element is a substance in which all atoms have the same identity.
- A compound is a substance that has two or more elements combined in a fixed proportion.

#### **Mixtures**

- A heterogeneous mixture is a mixture in which different materials can be distinguished easily.
- A homogeneous mixture contains two or more gaseous, liquid, or solid substances that are blended evenly throughout.
- Mixtures can be heterogeneous, homogeneous, colloids, or suspensions.

#### Self Check

- 1. **Describe** How is a compound similar to a homogeneous mixture? How is it different?
- 2. Distinguish between a substance and a mixture. Give two examples of each.
- 3. Describe the differences between colloids and suspensions.
- **4. Think Critically** Why do the words "Shake well before using" indicate that a fruit juice is a suspension?

## **Applying Math**

**5. Use Numbers** A polyester fabric is a mixture of 90 percent cotton and 10 percent polyester. If the fabric has a mass of 500 g, what is the mass of cotton in the fabric?



# **Comparing Pure Substances and Mixtures**

sample.

properties.

Everything you see that is made of matter is either a pure substance or a mixture. Some things, such as iron nails and aluminum foil, are elements; others, such as water and salt, are compounds. Steel, lemonade, concrete, and a bowl of fruit are all examples of mixtures.

Properties Table				
Substance	Matter Classification	Color	Magnetic Attraction	Density
	Do not writ	e in thi	book.	

**5. Determine** if each sample is magnetic.

**6. Determine** the mass of a 10-mL sample of

**7.** Try to separate the particles of the pepper-

sample can be separated by using physical

water mixture and the sugar water.

**8. Infer** if the different particles of each

each material. Calculate the density of each

#### 🥦 Real-World Problem

How do the properties of different pure substances and mixtures compare?

#### Goals

- Classify matter.
- **Calculate** density.
- **Compare** the properties of elements, compounds, and mixtures.

#### **Materials**

salt magnet iron filings balance funnel pepper water sugar water filter paper graduated cylinder magnifying lens 250-mL beakers (5)

# Conclude and Apply

- 1. **Describe** the separation methods of the mixture samples.
- 2. Infer how you can identify a substance as an element.
- **3. Calculate** the density of each material.

# **Safety Precautions**



# Procedure

- 1. Complete the safety form before you begin.
- **2.** Copy the data table into your Science Journal. Record all data in your table.
- **3. Determine** the color of each sample.
- 4. Classify each material as an element, compound, or mixture.



Identify experimental errors that might have occurred during the collection of your data.

# **Properties of Matter**

# **Reading Guide**

## What You'll Learn

- Identify substances using physical properties.
- Compare and contrast physical and chemical changes.
- Identify chemical changes.
- **Determine** how the law of conservation of mass applies to chemical changes.

# Why It's Important

Understanding chemical and physical properties can help you use materials properly.

#### Review Vocabulary

state of matter: one of three physical forms of matter: solid, liquid, or gas

#### New Vocabulary

- physical property
- physical change
- distillation
- chemical property
- chemical change
- law of conservation of mass



**Figure 10** Appearance is the most obvious physical property. **Describe** the appearance of these items.

# **Physical Properties**

You can stretch a rubber band, but you can't stretch a piece of string very much, if at all. You can bend a piece of wire, but you can't easily bend a matchstick. In each case, the materials change shape, but the identity of the substances—rubber, string, wire, and wood—does not change. The abilities to stretch and bend are physical properties. Any characteristic of a material that you can observe without changing the identity of the substances that make up the material is a physical property. Examples of other physical properties are color, shape, size, density, melting point, and boiling point. What physical properties can you use to describe the items in **Figure 10?** 

**Appearance** How would you describe a tennis ball? You could begin by describing its shape, color, and state of matter. You might describe the tennis ball as a brightly colored, hollow sphere. You can measure some physical properties, too. For instance, you could measure the diameter of the ball. What physical property of the ball is measured with a balance?

To describe a soft drink in a cup, you could start by calling it a liquid with a brown color. You could measure its volume and temperature. Each of these characteristics is a physical property of that soft drink.

Figure 11 The best way to separate substances depends on their physical properties. Size is the property used to separate poppy seeds from sunflower seeds in this example.



**Behavior** Some physical properties describe the behavior of a material or a substance. As you might recall, objects that contain iron, such as a safety pin, are attracted by a magnet. Attraction to a magnet (magnetism) is a physical property of the substance iron. Every substance has a specific combination of physical properties that make it useful for certain tasks. Some metals, such as copper, can be drawn out into wires. Others, such as gold, can be pounded into sheets as thin as 0.1 micrometers (µm), about 4-millionths of an inch. This property of gold makes it useful for decorating picture frames and other objects. Gold that has been beaten or flattened in this way is called gold leaf.

Think again about your soft drink. If you spill it, the drink will spread out over the table or floor. If you knock over a jar of molasses, however, it does not flow as easily. The ability to flow is a physical property of liquids.

Using Physical Properties to Separate Removing the seeds from a watermelon can be easily done based on the physical properties of the seeds compared to the rest of the fruit. **Figure 11** shows a mixture of poppy seeds and sunflower seeds. You can identify the two kinds of seeds by differences in color, shape, and size. By sifting the mixture, you could separate the poppy seeds from the sunflower seeds quickly because their sizes differ.

Now look at the mixture of iron filings and sand shown in **Figure 11.** You probably wouldn't be able to sift out the iron filings because they are similar in size to the sand particles. What you could do is pass a magnet through the mixture. The magnet will attract only the iron filings and pull them from the sand. This is an example of how a physical property, such as magnetic attraction, can be used to separate substances in a mixture. Something like this is done to separate iron for recycling.



What physical properties could be used to separate two different substances?



Magnetism easily separates iron from sand.



Recycling and Physical Properties Recycling conserves natural resources. In some large recycling projects, aluminum metal must be separated from scrap iron. What physical properties of the two metals could be used to separate them?



#### **Separating Ink**

#### **Procedure** STATE OF THE STATE

- **1.** Complete the safety form.
- 2. Cut a circle out of a clean. white coffee filter with a 9-cm diameter. Draw a spot using a nonperma**nent black marker** in the center of the filter.
- **3.** Place the filter on a **plate**. Using a dropper, place ten drops of water on the spot.

#### **Analysis**

Make a labeled drawing of your results in your Science **Journal.** What type of change did you observe? Explain.

# **Physical Changes**

If you break a piece of chewing gum, you change some of its physical properties—its size and shape. However, you do not change the identity of the materials that make up the gum.

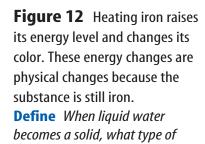
The Identity Remains the Same When a substance freezes, boils, evaporates, or condenses, it undergoes physical changes. A change in size, shape, or state of matter is called a physical change. Such a change might involve energy changes, but the kind of substance—the identity of the element or compound—does not change. Because all substances have distinct properties, such as densities, specific heats, and boiling and melting points, which are constant, these properties can be used to help identify them when a particular mixture contains substances that are not yet identified.



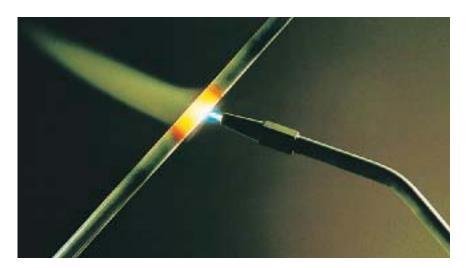
Does a change in state mean that a new substance has formed? Explain.

Iron is a substance that can change states if it absorbs or releases enough energy; at high temperatures, it melts. However, in both the solid and liquid state, iron has physical properties that identify it as iron. Color changes can accompany a physical change, too. For example, when iron is heated, it first glows red. Then, if it is heated to a higher temperature, it turns white, as shown in **Figure 12.** 

Using Physical Change to Separate A cool drink of water is something most people take for granted, but in some parts of the world, drinkable water is scarce. Not enough drinkable water can be obtained from wells. Many such areas that lie close to the ocean obtain drinking water by using the physical properties of water to separate it from the salt. One separation method, which uses the property of boiling point, is distillation.

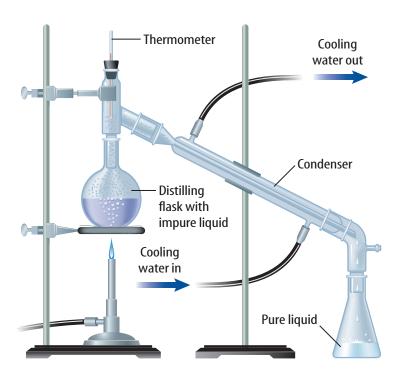


physical change occurs?



**Distillation** The process used for separating substances in a mixture by evaporating a liquid and recondensing its vapor is **distillation**. It usually is done in the laboratory using an apparatus similar to that shown in Figure 13. The liquid vaporizes and condenses, leaving the solid material behind.

Two liquids having different boiling points can be separated in a similar way. The mixture is heated slowly until it begins to boil. Vapors of the liquid with the lowest boiling point form first and are condensed and collected. Then, the temperature is increased until the second liquid boils, condenses, and is collected. Distillation is used often in industry. Natural oils such as mint are distilled.



# **Chemical Properties and Changes**

You probably have seen warnings on cans of paint thinners and lighter fluids for charcoal grills that say these liquids are flammable (FLA muh buhl). The tendency of a substance to burn, or its flammability, is an example of a chemical property. Burning produces a new substance during a chemical change. A chemical property is a characteristic of a substance that indicates whether it can undergo a certain chemical change. Many substances used around the home, such as lighter fluids, are flammable. Knowing which ones are flammable helps you to use them safely.

A less-dramatic chemical change can affect some medicines. Look at **Figure 14.** You probably have seen bottles like this in a pharmacy. Many medicines are stored in dark bottles because they contain compounds that can change chemically if they are exposed to light.

Figure 13 Distillation can easily separate liquids from solids dissolved in them. The liquid is heated until it vaporizes and moves up the column. Then, as it touches the water-cooled surface of the condenser, it becomes liquid again.



**Figure 14** The brown color of these bottles tells you that these vitamins may react to light. Reaction to light is a chemical property.



Alchemy In the Middle Ages, alchemy was an early form of chemistry devoted to the study of changing baser metals into gold and also to finding the elixir of perpetual youth. Based on what we know now about the properties of metals and biology, it is easy to understand why this field of study is no longer practiced.

# **Detecting Chemical Changes**

If you leave a pan of chili cooking unattended on the stove for too long, your nose soon tells you that something is wrong. Instead of a spicy aroma, you detect an unpleasant smell that alerts you that something is burning. This burnt odor is a clue that a new substance has formed.

**The Identity Changes** The smell of rotten eggs and the formation of rust on bikes or car fenders are signs that chemical changes have taken place. A change of one substance to another is a **chemical change.** The foaming of an antacid tablet in a glass of water and the smell in the air after a thunderstorm are other signs of new substances being produced. In some chemical changes, a rapid release of energy—detected as change of heat, light, and/or sound production—is a clue that changes are occurring.

# Reading Check What is a chemical change?

A clue such as heat, cooling, or the formation of bubbles or solids in a liquid is a helpful indicator that a chemical reaction is taking place. However, the only sure proof is that a new substance is produced. Consider the following example. The heat, light, and sound produced when hydrogen gas combines with oxygen in a rocket engine are clear evidence that a chemical reaction has taken place. But no clues announce the reaction that takes place when iron combines with oxygen to form rust because the reaction takes place so slowly. The only clue that iron has changed into a new substance is the presence of rust. Burning and rusting are chemical changes because new substances form. You sometimes can follow the progress of a chemical reaction visually. For example, you can see lead nitrate forming in **Figure 15.** 





**Figure 15** The solid forming from two liquids is another sign that a chemical reaction has taken place.

**Identify** *clues that show a reaction* has taken place.

**Using Chemical Change to Separate** You might separate substances using a chemical change when cleaning tarnished silver. Tarnish is a chemical reaction between silver metal and sulfur compounds in the air that results in silver sulfide. It can be changed back into silver with a chemical reaction. This chemical reversal back to silver takes place when the tarnished item is placed in a warm water bath with baking soda and aluminum foil. You don't usually separate substances using chemical changes in the home. In industry and chemical laboratories, however, this kind of separation is common. For example, many metals are separated from their ores and then purified using chemical changes.

# **Weathering—Chemical** or Physical Change?

The forces of nature continuously shape Earth's surface. Rocks split, deep canyons are carved out, sand dunes shift, and curious limestone formations decorate caves. Do you think these changes, often referred to as weathering, are physical or chemical? The answer is both. Geologists, who use the same criteria that you have learned in this chapter, say that some weathering changes are physical and some are chemical.

**Physical** Large rocks can split when water seeps into small cracks, freezes, and expands. However, the smaller pieces of newly exposed rock still have the same properties as the original sample. This is a physical change. Streams can cut through softer rock, forming canyons, and can smooth and sculpt harder rock, as shown on the left in **Figure 16.** In each case, the stream carries rock particles far downstream before depositing them. Because the particles are unchanged, the change is a physical one.

Flowing water shaped and smoothed these rocks in a physical process.



Both chemical and physical changes shaped the famous White Cliffs of Dover lining the English Channel.



Chemical Reactions and **Lightning** In a thunderstorm, light and sound tell you that changes have occurred. The pungent smells of ozone indicates that a chemical reaction also took place. Lightning converts oxygen gas, O<sub>2</sub>, into ozone, O<sub>3</sub>. Ozone is unstable and soon breaks up, forming oxygen again.

**Figure 16** Weathering can involve physical or chemical change.



#### **Topic: Caves**

Visit gpescience.com for Web links to information about cave formations.

**Activity** Describe the formation of stalactites and stalagmites. Explain the differences between the two and whether they are the result of a physical and/or chemical process.

**Chemical** In other cases, the change is chemical. For example, solid calcium carbonate, a compound that mostly makes up limestone, does not dissolve easily in water. However, when the water is even slightly acidic, as it is when it contains some dissolved carbon dioxide, calcium carbonate reacts. It changes into a new substance, calcium hydrogen carbonate, which does dissolve in water. This change in limestone is a chemical change because the identity of the calcium carbonate changes. The White Cliffs of Dover, shown on the right in **Figure 16**, are made of limestone and undergo such chemical changes, as well as physical changes. A similar chemical change produces caves and the icicle-shaped rock formations that often are found in them.

# **Applying Math**

#### **Calculate**

**THE LAW OF CONSERVATION OF MASS** When a chemical reaction takes place, the total mass of reactants equals the total mass of products. If 18 g of hydrogen reacts completely with 633 g of chlorine, how many grams of HCl are formed?  $H_2 + Cl_2 \rightarrow 2HCl$ 

IDENTIFY known values and the unknown value

Identify the known values:

mass of 
$$H_2 = 18 g$$

mass of 
$$Cl_2 = 633 g$$

mass of reactants = mass of products

Identify the unknown value:

**SOLVE** the problem

Solve for the mass of HCl. 
$$g H_2 + g Cl_2 = g HCl$$

Substitute the known values. 18 g + 633 g = 651 g HCl

**CHECK** the answer

Does your answer seem reasonable? Check your answer by subtracting the mass of H<sub>2</sub> from the mass of HCl. Do you obtain the mass of the Cl<sub>2</sub>? If so, the answer is correct.

## **Practice Problems**

- 1. In the following reaction, 24 g of CH<sub>4</sub> (methane) reacts completely with 96 g of O<sub>2</sub> to form 66 g of  $CO_2$ . How many grams of  $H_2O$  are formed?  $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
- 2. In the following equation, 54.0 g of Al reacts completely with 409.2 g of ZnCl<sub>2</sub> to form 196.2 g of Zn metal. How many grams of AlCl<sub>3</sub> are formed?  $2Al + 3ZnCl_2 \rightarrow 3Zn + 2AlCl_3$

For more practice problems go to page 879, and visit Math Practice at gpescience.com.

## **The Conservation of Mass**

Wood is combustible, or burnable. As you just learned, this is a chemical property. Suppose you burn a large log in a fireplace, as shown in Figure 17, until nothing is left but a small pile of ashes. Smoke, heat, gas, and light are given off, and the changes in the appearance of the log confirm that a chemical change took place. You might think that matter was lost during this change because the pile of ashes looks much smaller than the log did. In fact, the mass of the ashes is less than that of the log. Suppose that you could collect all the oxygen in the air that was combined

with the log during the burning and all the smoke, heat, light, and gases that escaped from the burning log and measure their masses, too. Then you would find that no mass was lost after all.

Not only is no mass lost during burning, mass is not gained or lost during any chemical change. In other words, matter is neither created nor destroyed during a chemical change. According to the law of conservation of mass, the mass of all substances that are present before a chemical change equals the mass of all the substances that remain after the change.



Explain what is meant by the law of conservation of mass.



**Figure 17** This reaction appears to be destroying these logs. When it is over, only ashes will remain. Yet you know that no mass is lost in a chemical reaction.

**Explain** why this is so.

#### section review

#### **Summary**

#### **Physical Properties**

 You can observe physical properties without changing the identity of a substance.

#### **Physical Changes**

• Change in the size, shape, or state of matter is a physical change.

#### **Chemical Properties and Changes**

- A chemical property is a characteristic of a substance that indicates whether it can undergo a certain chemical change.
- A change of one substance to another is a chemical change.
- Many metals are separated from their ores and purified using chemical changes.

#### **Self Check**

- 1. Explain why evaporation of water is a physical change and not a chemical change.
- 2. List four physical properties you could use to describe a liquid.
- 3. **Describe** why flammability is a chemical property rather than a physical property.
- 4. Explain how the law of conservation of mass applies to chemical changes.
- 5. Think Critically How might you demonstrate the law of conservation of mass for melting ice and distilling water?

# **Applying Math**

**6. Calculate** In the following equation, 417.96 g of Bi (bismuth) reacts completely with 200 g of F (fluorine). How many grams of BiF<sub>3</sub> (bismuth fluoride) are formed? 2 Bi + 3  $F_2 \rightarrow$  2 Bi $F_3$ 



# **Design Your Own**

# **Measuring the Conservation of Mass**

#### Goals

- Measure the total mass of water and antacid tablets before and after the tablets are dissolved in the water.
- **Compare** the total mass of water and tablets before and after the tablets are dissolved in the water.
- **Infer** whether or not the law of conservation of mass applies to antacid tablets dissolving in water

#### **Possible Materials**

antacid tablets empty plastic drink bottle balloon

beaker

water

spatula

balance

mortar

pestle

funnel

## **Safety Precautions**



Do not eat the antacid tablet.

# 🕽 Real-World Problem

Have you ever watched burning logs in a fireplace? If you have, you might have noticed many large logs being burned in the hearth during an evening. At the end of the night, nothing more than a pile of ash remains. In this lab, your group will design an experiment to demonstrate the law of conservation of mass. Is the mass of antacid tablets conserved after they are dissolved?

# Form a Hypothesis

Based on your understanding of mass conservation, form a hypothesis that predicts the total mass of antacid tablets and water before and after the tablets are dissolved.

# Test Your Hypothesis

#### Make a Plan

- 1. Complete the safety form before you begin.
- **2.** As a group, agree upon and write the hypothesis statement.
- 3. Decide upon any safety equipment you need or safety procedures you need to devise to ensure the safety of your group during the experiment.



# Using Scientific Methods

- **4. Plan** an experiment to test your hypothesis. List the steps of your experiment.
- List the materials you need to test your hypothesis.
- 6. Have one group member reread your entire experiment aloud to the group to make certain you have all the necessary materials and that your experimental steps can be easily followed.



- 1. Make sure your teacher approves your plan.
- Copy the data table into your Science Journal to record measurements.
- **3.** While doing the experiment, write your observations, and complete the data table in your Science Journal.

# Analyze Your Data

- **1. Describe** the effects of the chemical reaction between the antacid powder and the water.
- **2. Compare** the total mass of the substances before the reaction to their mass after the reaction.
- **3. Graph** the mass of the substances before and after the reaction using a bar graph.
- **4. Explain** if your data supported your hypothesis.

# Conclude and Apply

- Identify possible experimental errors in your experiment design.
- **2. Infer** how mass might have been lost or added between the initial and final weighing of the substances.
- **3. Infer** what the expected mass of the substances should be after the chemical reaction occurred.



Data Table			
Trial Number	Mass Before Reaction	Mass After Reaction	
Do	not write in this	book.	



**Compare** the data your group collected with the data collected by the other groups and discuss possible reasons for differences in the data.

# SCIENCE Stats

# **Intriguing Elements**

# Did you know...

... Silver-white cobalt, which usually is combined with other elements in nature, is used to create rich paint pigments. It can be used to form powerful magnets, treat cancer patients, build jet engines, and prevent disease in sheep.

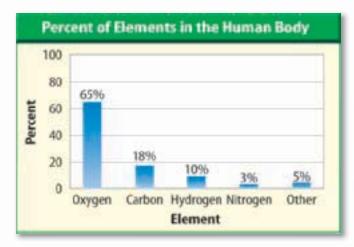


#### ... Gold is the most ductile

(stretchable) of all the elements. Just 29 g of gold—about ten wedding bands—can be pulled into a wire 100 km long. That's long enough to stretch from

Toledo, Ohio, to Detroit, Michigan, and beyond.





... Zinc makes chewing gum taste better. Up to 0.3 mg of zinc acetate can be added per 1000 mg of chewing gum to provide a tart, zingy flavor.

## **Applying Math**

- 1. Zinc acetate is approximately 35 percent zinc. How many grams of chewing gum would be needed to provide a total of 10.0 mg of zinc?
- 2. If you wanted to produce a gold wire with the same diameter as mentioned in the example above, how many grams would be needed to make a wire one meter in length?
- **3.** Table sugar has the chemical formula  $C_{12}H_{22}O_{11}$ . If you were going to build a scale model of sucrose (table sugar) and you had 36 model carbon atoms, how many of each of the others (hydrogen and oxygen) would you need to build an accurate, complete sucrose model?



# **Reviewing Main Ideas**

# **Section 1** Composition of Matter

- 1. Elements and compounds are substances. A mixture is composed of two or more substances.
- **2.** You can distinguish between the different materials in a heterogeneous mixture using either your unaided eye or a microscope.
- **3.** Colloids and suspensions are two types of heterogeneous mixtures. The particles in a suspension will settle eventually. Particles of a colloid will not. Milk is an example of a colloid.
- 4. In a homogeneous mixture, the particles are distributed evenly and are not visible, even when using a microscope. Homogeneous mixtures can be composed of solids, liquids, or gases.
- **5.** A solution is another name for a homogeneous mixture that remains constantly and uniformly mixed.



This is a clear indication that this mixture is a suspension.

#### **Properties of Matter** Section 2

- **1.** Physical properties are characteristics of materials that you can observe without changing the identities of the substances.
- **2.** Chemical properties indicate what chemical changes substances can undergo. Many medicines are stored in dark bottles because they react with light.
- **3.** In physical changes, the identities of substances remain unchanged.
- **4.** In chemical changes, the identities of substances change: new substances are formed. A visible chemical change takes place when rust is cleaned with bleach.



**5.** The law of conservation of mass states that during any chemical change, matter is neither created nor destroyed.

FOLDABLES Use the Foldable that you made at the beginning of the chapter to help you review the classification of matter.

# **Using Vocabulary**

chemical change p. 564
chemical property p. 563
colloid p. 556
compound p. 554
distillation p. 563
element p. 552
heterogeneous mixture
p. 555
homogeneous mixture
p. 556

law of conservation of mass p.567 physical change p.562 physical property p.560 solution p.556 substance p.552 suspension p.558 Tyndall effect p.557

Complete each sentence with the correct vocabulary word or words.

- **1.** Substances formed from atoms of two or more elements are called \_\_\_\_\_.
- **2.** A(n) \_\_\_\_\_ is a heterogeneous mixture in which visible particles settle.
- **3.** Freezing, boiling, and evaporation are all examples of \_\_\_\_\_.
- **4.** According to the \_\_\_\_\_\_, matter is neither created nor destroyed during a chemical change.
- **5.** A mixture in which different materials are easily identified is \_\_\_\_\_.
- **6.** Compounds are made from different atoms of two or more \_\_\_\_\_.
- **7.** Distillation is a process that can separate two liquids using \_\_\_\_\_.

# **Checking Concepts**

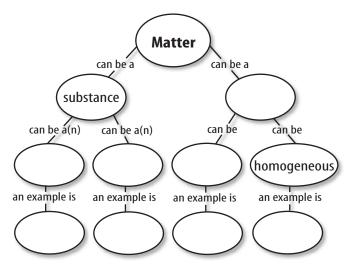
Choose the word or phrase that best answers the question.

- **8.** Bending a copper wire is an example of what property?
  - A) chemical
- **c)** element
- **B)** conservation
- **D)** physical

- **9.** Which is **NOT** an element?
  - **A)** carbon
- **c)** oxygen
- **B)** hydrogen
- **D)** water
- **10.** Which is an example of a chemical change?
  - **A)** boiling
- **c)** evaporation
- **B)** burning
- **D)** melting
- **11.** What is gelatin?
  - A) colloid
- **C)** substance
- **B)** compound
- **D)** suspension
- **12.** Which is an example of a visible sunbeam?
  - A) an element
- c) a compound
- **B)** a solution
- **D)** the Tyndall effect
- **13.** How would you classify the color of a rose?
  - A) chemical change
  - **B)** chemical property
  - **c)** physical change
  - **D)** physical property
- **14.** How would you describe the process of evaporating water from seawater?
  - A) chemical change
  - **B)** chemical property
  - **C)** physical change
  - **D)** physical property
- **15.** Which is a substance?
  - **A)** colloid
- c) mixture
- **B)** element
- **D)** solution
- **16.** Which property can be used to help identify an unknown substance?
  - **A)** specific heat
- **c)** temperature
- **B)** combustion
- **D)** Tyndall effect
- **17.** Which statement about the law of conservation of mass is **TRUE**?
  - **A)** Mass is created only.
  - **B)** Mass is created and destroyed.
  - **c)** Mass is destroyed only.
  - **D)** Mass is neither created nor destroyed.

## Interpreting Graphics

**18.** Copy and complete the concept map below about matter.



Use the table below to answer question 19.

Common Colloids		
Colloid	Example	
Solid in a liquid	Gelatin	
Solid in a gas		
Gas in a solid	Do not	
Solid in a liquid	write in this book.	
Liquid in a gas		

**19. Identify** how different colloids can involve different states. For example, gelatin is formed from solid particles in a liquid. Complete the table using these colloids: smoke, marshmallow, fog, and paint.

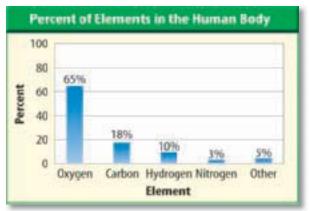
# Thinking Critically

- **20.** Compare and contrast elements and compounds. Give two examples of each.
- **21. Explain** Carbon and the gases hydrogen and oxygen combine to form sugar. How do you know sugar is a compound?

- **22.** Use a nail rusting in air to explain the law of conservation of mass.
- **23.** Use Variables, Constants, and Controls Marcos took a 100-cm<sup>3</sup> sample of a suspension, shook it well, and poured equal amounts into four different test tubes. He placed one test tube in a rack, one in hot water, one in warm water, and the fourth in ice water. He then observed the time it took for each suspension to settle. What was the variable in the experiment? What was one constant?
- **24. Concept Map** Make a network tree to show types of liquid mixtures. Include these terms: homogeneous mixtures, heterogeneous mixtures, solutions, colloids, and suspensions.

#### **Applying Math**

Use the graph below to answer question 25.



- **25.** Use Proportions If you had 50 atoms of hydrogen, how many atoms each of oxygen, carbon, and nitrogen would you need to have the elements in the same proportion as they are in your body?
- **26.** Use Numbers In the following equation, 243.5 g of Sb (antimony) reacts completely with 1000 g of I<sub>2</sub> (iodine) to form 1004.9 g of SbI<sub>3</sub> (antimony triiodide). How many grams of I<sub>2</sub> were consumed in the reaction? 2 Sb + 3  $I_2 \rightarrow 2$  Sb $I_3$

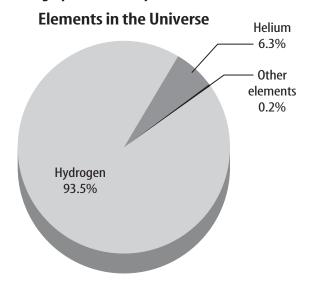
# Standardized Test Practice chapter

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### Multiple Choice

- **1.** CaCO<sub>3</sub> is an example of which type of material?
  - A. colloid
  - **B.** compound
  - **C.** element
  - **D.** mixture

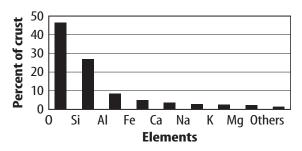
#### Use the graph to answer question 2.



- **2.** What percentage do the elements hydrogen and helium account for in the universe?
  - A. 100 percent
  - **B.** 99.9 percent
  - **c.** 99.8 percent
  - **D.** 98 percent

#### Use the graph below to answer question 3.

#### **Elements in Earth's Crust**



- **3.** Which element makes up 8 percent of Earth's crust?
  - A. aluminum
  - B. iron
  - C. oxygen
  - **D.** silicon
- **4.** Which element has the physical property of magnetism?
  - A. calcium
  - **B.** iron
  - C. oxygen
  - **D.** sodium
- **5.** Which statement best decribes the law of conservation of mass?
  - **A.** The mass of the products is always greater than the mass of the materials that react in a chemical change.
  - **B.** The mass of the products is always less than the mass of the materials that react in a chemical change.
  - **c.** A certain mass of material must be present for a reaction to occur.
  - **D.** Matter is neither lost nor gained during a chemical change.

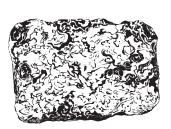
- **6.** The most plentiful element in the universe readily burns in air. What is this chemical property called?
  - A. flammability
  - **B.** ductility
  - **c.** density
  - **D.** boiling point

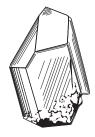
#### Gridded Response

- **7.** In the following reaction, 24 g of CH<sub>4</sub> (methane) react completely with 96 g of O<sub>2</sub> to form 66 g of CO<sub>2</sub>. How many grams of H<sub>2</sub>O are formed?
- **8.** A reaction of 22.85 g of sodium hydroxide (NaOH) with 20.82 g of hydrogen chloride (HCl) gives off 10.29 g of water ( $H_2O$ ). What mass of sodium chloride (NaCl) is formed in this reaction?

## **Short Response**

Use the illustration below to answer questions 9.





**9.** What physical properties could be used to identify these minerals?

**10.** You are given a mixture of iron filings, sand, and salt. Describe how to separate this mixture.

#### **Extended Response**

**11.** Describe how a compound is a combination of elements in a fixed proportion. Give two examples.

Use the illustration below to answer question 12.



**12.** Design an experiment that shows that this type of chemical change is governed by the law of conservation of mass.

#### Test-Taking Tip

**Directions and Instructions** Listen carefully to the instructions from your teacher. Read the directions and each question carefully.

# chapter

#### BIG (Idea

The properties of an element are determined by the composition of its atoms.

#### 19.1 Structure of the Atom

MAIN (Idea Protons and neutrons are located in an atom's nucleus, and electrons are located in an electron cloud surrounding the nucleus.

#### 19.2 Masses of Atoms

MAIN (Idea All atoms of the same element have the same number of protons but can have different numbers of neutrons.

#### 19.3 The Periodic Table

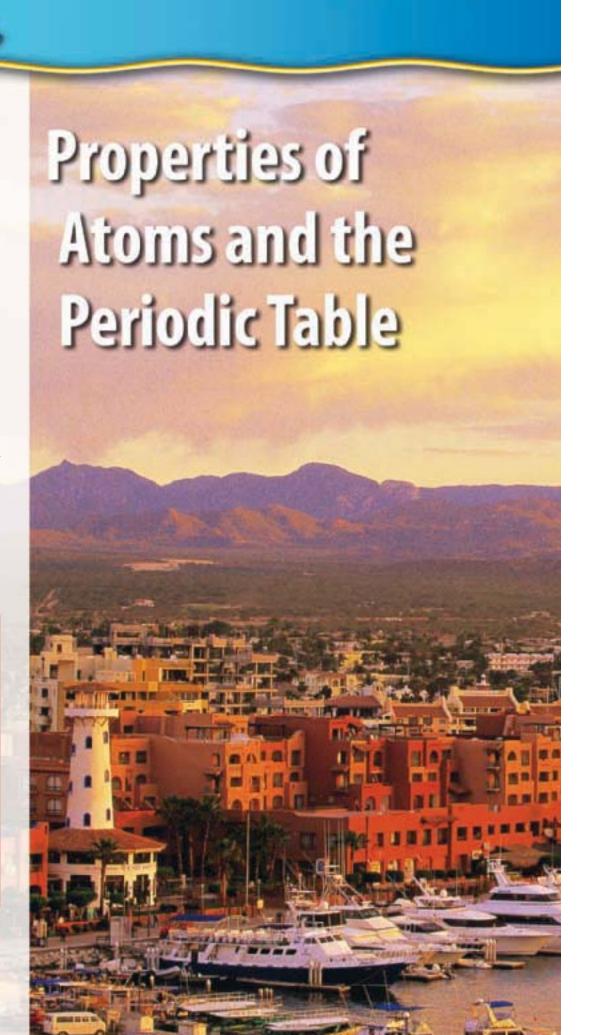
MAIN (Idea Atoms of elements that are in the same group on the periodic table contain the same number of outer energy level electrons.

# Atoms Compose All Things — Great and Small

Everything in this photo and the universe is composed of tiny particles called atoms. You will learn about atoms and their components—protons, neutrons, electrons, and quarks.

#### **Science Journal**

In your Science Journal, write a few paragraphs about what you know about atoms.



# **Start-Up Activities**



# **Inferring What You Can't Observe**

How do scientists study atoms when they cannot see them? In situations such as these, techniques must be developed to find clues to answer questions. Do the lab below to see how clues might be gathered.



- 1. Complete the safety form.
- **2.** Take an envelope and several items from your teacher.
- **3.** Place an assortment of items in the envelope and seal it.
- **4.** Trade envelopes with another group.
- 5. Without opening the envelope, try to figure out the types and number of items that are in the envelope. Record a hypothesis about the contents of the envelope in your Science Journal.
- **6.** After you record your hypothesis, open the envelope and see what is inside.
- **7. Think Critically** Describe the contents of your envelope. Was your hypothesis correct?



Preview this chapter's content and activities at gpescience.com



**Atoms** You have probably studied atoms before. Make the following Foldable to help iden-

tify what you already know, what you want to know, and what you learn about atoms.

Fold a sheet of paper vertically from side to side. Make the front edge about

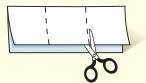
the front edge about 1.25 cm shorter than the back edge.



Turn lengthwise and fold into thirds.



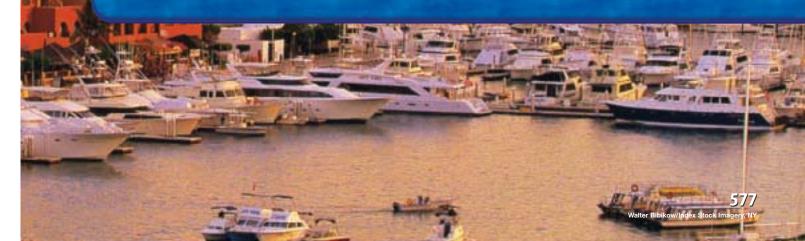
STEP 3 Unfold and cut only the top layer along both folds to make three tabs.



STEP 4 Label each tab as shown.



Identify Questions Before you read the chapter, write what you already know about atoms under the left tab of your Foldable, and write questions about what you'd like to know under the center tab. After you read the chapter, list what you learned under the right tab.



# **Structure of the Atom**

# **Reading Guide**

# What You'll Learn

- Identify the names and symbols of common elements.
- Identify quarks as subatomic particles of matter.
- Describe the electron cloud model of the atom.
- **Explain** how electrons are arranged in an atom.

# Why It's Important

Everything that you see, touch, and breathe is composed of tiny atoms.

# Review Vocabulary

**element:** substance with atoms that are all alike

#### New Vocabulary

- atom
- nucleus
- proton
- neutron
- electron
- quark
- electron cloud

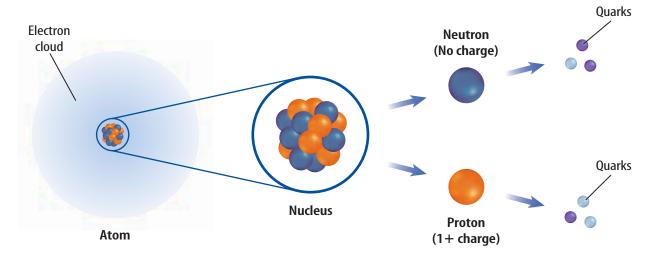
# **Scientific Shorthand**

Do you have a nickname? Do you use abbreviations for long words or the names of states? Scientists also do this. In fact, scientists have developed their own shorthand for dealing with long, complicated names.

Do the letters C, Al, Ne, and Ag mean anything to you? Each letter or pair of letters is a chemical symbol, which is a short or abbreviated way to write the name of an element. Chemical symbols, such as those in **Table 1**, consist of one capital letter or a capital letter plus one or two lowercase letters. For some ele-

Table 1 Symbols of Some Elements				
Element	Symbol	Element	Symbol	
Aluminum	Al	Iron	Fe	
Calcium	Ca	Mercury	Hg	
Carbon	C	Nitrogen	N	
Chlorine	Cl	Oxygen	0	
Gold	Au	Potassium	K	
Hydrogen	Н	Sodium	Na	

ments, the symbol is the first letter of the element's name. For other elements, the symbol is the first letter of the name plus another letter from its name. Some symbols are derived from Latin. For instance, *argentum* is Latin for "silver." Elements have been named in a variety of ways. Some elements are named to honor scientists, for places, or for their properties. Other elements are named using rules established by an international committee. Regardless of the origin of the names, scientists derived this international system for convenience. It is much easier to write H for hydrogen, O for oxygen, and H<sub>2</sub>O for dihydrogen oxide (water) than to write out the names. Because scientists worldwide use this system, everyone understands what the symbols mean.



# **Atomic Components**

An element is matter that is composed of one type of **atom**, which is the smallest piece of matter that still retains the property of the element. For example, the element silver is composed of only silver atoms, and the element hydrogen is composed of only hydrogen atoms. Atoms are composed of particles called protons, neutrons, and electrons, as shown in **Figure 1.** Protons and neutrons are found in a small, positivelycharged center of the atom called the nucleus, which is surrounded by a cloud containing electrons. **Protons** are particles with an electrical charge of 1+. Neutrons are neutral particles that do not have an electrical charge. **Electrons** are particles with an electrical charge of 1—. Atoms of different elements differ in the number of protons they contain.



What are the particles that make up the atom and where are they located?

# **Quarks: Even Smaller Particles**

Are the protons, electrons, and neutrons that make up atoms the smallest particles that exist? Scientists hypothesize that electrons are not composed of smaller particles and are one of the most basic types of particles. Protons and neutrons, however, are made up of smaller particles called quarks. So far, scientists have confirmed the existence of six uniquely different quarks. Scientists theorize that an arrangement of three quarks held together with the strong nuclear force produces a proton. Another arrangement of three quarks produces a neutron. The search for the composition of protons and neutrons is an ongoing effort.

**Figure 1** The nucleus of the atom contains protons and neutrons that are composed of quarks. The proton has a positive charge and the neutron has no charge. A cloud of negatively charged electrons surrounds the nucleus of the atom.

Explain how atoms of different elements differ.



## **Topic: Particle Research**

Visit gpescience.com for Web links to information about particle research at Fermi National Accelerator Laboratory.

**Activity** Write a paragraph describing the information that you found at the site.

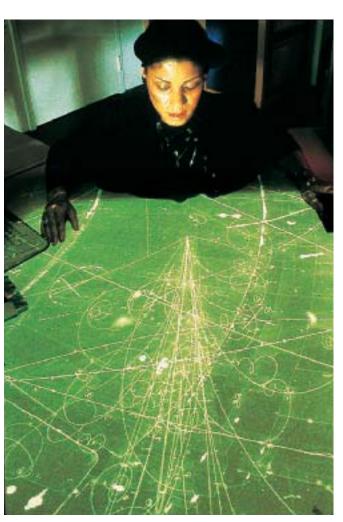
**Figure 2** The Tevatron is a huge machine. The aerial photograph of Fermi National **Accelerator Laboratory shows** the circular outline of the Tevatron particle accelerator. The close-up photograph of the Tevatron gives you a better view of the tunnel.

**Infer** Why is such a long tunnel needed?





Figure 3 Bubble chambers can be used by scientists to study the tracks left by subatomic particles.



**Finding Quarks** To study quarks, scientists accelerate charged particles to tremendous speeds and then force them to collide with—or smash into—protons. This collision causes the proton to break apart. The Fermi National Accelerator Laboratory, a research laboratory in Batavia, Illinois, houses a machine that can generate the forces that are required to make protons collide. This machine, the Tevatron, shown in **Figure 2**, is approximately 6.4 km in circumference. Electric and magnetic fields are used to accelerate, focus, and make the fast-moving particles collide.

> The particles that result from the collision can be detected by various collection devices. Often, scientists use multiple collection devices to collect the greatest possible amount of information about the particles created in a collision. Just as police investigators can reconstruct traffic accidents from tire marks and other clues at the scene, scientists are able to examine and gather information about the particles, as shown in Figure 3. Scientists use inferences to identify the subatomic particles and to discover information about each particle's inner structure.

> **The Sixth Quark** Finding evidence for the existence of quarks was not an easy task. Scientists found five quarks and hypothesized that a sixth quark existed. However, it took a team of nearly 450 scientists from around the world several years to find the sixth quark. The tracks of the sixth quark were hard to detect because only about one-billionth of a percent of the proton collisions performed showed the presence of a sixth quark, typically referred to as the top quark.

## **Models—Tools for Scientists**

Scientists and engineers use models to represent things that are difficult to visualize or picture in the mind. You might have seen models of buildings, the solar system, or airplanes. These are scaled-down models. Scaled-down models allow you to see either something too large to see all at once or something that has not been built yet. Scaled-up models are often used to visualize things that are too small to see. To give you an idea of how small the atom is, it would take about 24,400 atoms stacked one on top of the other to equal the thickness of a sheet of aluminum foil. To study the atom, scientists have developed scaledup models that they can use to visualize how the atom is constructed. For the model to be useful, it must support all of the information that is known about matter and the behavior of atoms. As more information about the atom is collected, scientists change their models to include the new information.



**Reading Check** Explain how models can simplify science.

The Changing Atomic Model You know now that all matter is composed of atoms, but this was not always known. Around 400 B.C., Democritus proposed the idea that atoms make up all substances. However, another famous Greek philosopher, Aristotle, disputed Democritus's theory and proposed that matter is uniform throughout and is not composed of smaller particles. Aristotle's incorrect theory was accepted for about 2000 years. In the 1800s, John Dalton, an English scientist, was able to offer proof that atoms exist.

Dalton's model of the atom, a solid sphere shown in Figure 4, was an early model of the atom. As you can see in Figure 5, the model has changed somewhat over time. Dalton's modernization of Aristotle's idea of the atom provided a physical explanation for chemical reactions. Scientists could then express these reactions in quantitative terms using chemical symbols and equations.



#### **Modeling an Aluminum Atom**

#### Procedure m

- 1. Complete the safety form.
- 2. Arrange thirteen 3-cm circles cut from orange paper and fourteen 3-cm circles cut from **blue paper** on a flat surface to represent the nucleus of an atom. Each orange circle represents one proton, and each blue circle represents one neutron.
- 3. Position two holes punched from red paper about 20 cm from your nucleus.
- 4. Position eight punched holes about 40 cm from your nucleus.
- 5. Position three punched holes about 60 cm from your nucleus.

#### **Analysis**

- 1. How many protons, neutrons, and electrons does an aluminum atom have?
- 2. Explain how your circles model an aluminum atom.
- 3. Explain why your model does not accurately represent the true size and distances in an aluminum atom.



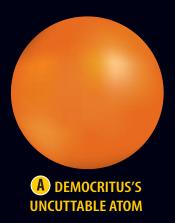


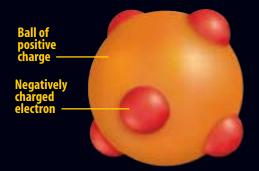
**Figure 4** John Dalton's atomic model was a simple sphere.

# NATIONAL GEOGRAPHIC VISUALIZING THE ATOMIC MODEL

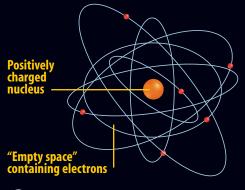
#### Figure 5

he ancient Greek philosopher Democritus proposed that elements consist of tiny, solid particles that cannot be subdivided (A). He called these particles atomos, meaning "uncutable." This concept of the atom's structure remained largely unchallenged until the 1900s, when researchers began to discover through experiments that atoms are composed of still smaller particles. In the early 1900s, a number of models for atomic structure were proposed (B-D). The currently accepted model (E) evolved from these ideas and the work of many other scientists.

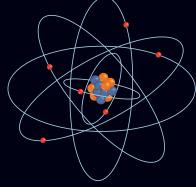




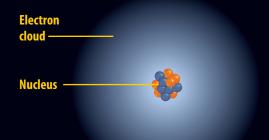
B THOMSON MODEL, 1904 English physicist Joseph John Thomson inferred from his experiments that atoms contain small, negatively charged particles. He thought these "electrons" (in red) were evenly embedded throughout a positively charged sphere, much like chocolate chips in a ball of cookie dough.



RUTHERFORD MODEL, 1911 Another British physicist, Ernest Rutherford, proposed that almost all the mass of an atom—and all its positive charges—is concentrated in a central atomic nucleus surrounded by electrons.



D BOHR MODEL, 1913 Danish physicist Niels Bohr hypothesized that electrons travel in fixed orbits around the atom's nucleus. James Chadwick, a student of Rutherford, concluded that the nucleus contains positive protons and neutral neutrons.

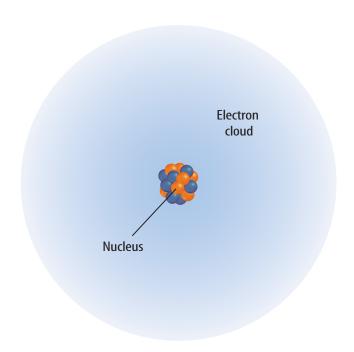


E ELECTRON CLOUD MODEL, CURRENT According to the currently accepted model of atomic structure, electrons do not follow fixed orbits but tend to occur more frequently in certain areas around the nucleus at any given time.

The Electron Cloud Model By 1926, scientists had developed the electron cloud model of the atom that is in use today. An electron cloud is the area around the nucleus of an atom where its electrons are most likely found. The electron cloud is 100,000 times larger than the diameter of the nucleus. In contrast, each electron in the cloud is much smaller than a single proton.

Because an electron's mass is small and the electron is moving so quickly around the nucleus, it is impossible to describe its exact location in an atom. Picture the spokes on a moving bicycle wheel. They are moving so quickly that you can't pinpoint any single spoke. All you see is a blur that contains all of the spokes somewhere within it. In the same

way, an electron cloud is a blur containing all of the electrons of the atom somewhere within it. Figure 6 illustrates what the electron cloud might look like.



**Figure 6** The electrons are located in an electron cloud surrounding the nucleus of the atom.

# section

## Summary

#### **Scientific Shorthand**

 Scientists use chemical symbols as shorthand when writing the names of elements.

#### **Atomic Components**

- Atoms are composed of small particles that have known charges.
- Atoms of different elements differ in the number of protons they contain.

#### **Quarks: Even Smaller Particles**

• So far, scientists have confirmed the existence of six different quarks.

#### **Models: Tools for Scientists**

- Models are used by scientists to simplify the study of concepts and things.
- The current atomic model is an accumulation of over 200 years of knowledge.
- The electron cloud model is the current atomic model.

# **Self Check**

review

- 1. List the chemical symbols for the elements carbon, aluminum, hydrogen, oxygen, and sodium.
- **2. Identify** the names, charges, and locations of three kinds of particles that make up an atom.
- **3. Identify** the smallest particle of matter. How were these particles discovered?
- 4. **Describe** the electron cloud model of the atom.
- **5. Think Critically** Explain how a rotating electric fan might be used to model the atom. Explain how the rotating fan is unlike an atom.

#### **Applying Math**

- **6. Use Numbers** The mass of a proton is estimated to be  $1.6726 \times 10^{-24}$  g, and the mass of an electron is estimated to be 9.1093  $\times$  10<sup>-28</sup> g. How many times larger is the mass of a proton than the mass of an electron?
- **7. Calculate** What is the difference between the mass of a proton and the mass of an electron?

# **Masses of Atoms**

# **Reading Guide**

#### What You'll Learn

- Compute the atomic mass and mass number of an atom.
- Identify the components of isotopes.
- Interpret the average atomic mass of an element.

# Why It's Important

Some elements naturally exist in more than one form—radioactive and nonradioactive.

## Review Vocabulary

mass: amount of matter in an object

#### **New Vocabulary**

- atomic number
- mass number
- isotope
- average atomic mass

# Table 2SubatomicParticle Masses

i di ticic masses		
Particle	Mass (g)	
Proton	$1.6726 \times 10^{-24}$	
Neutron	$1.6749 \times 10^{-24}$	
Electron	$9.1093 \times 10^{-28}$	

# **Atomic Mass**

The nucleus contains most of the mass of an atom because protons and neutrons are far more massive than electrons. The mass of a proton is about the same as that of a neutron—approximately  $1.6726 \times 10^{-24}$  g, as shown in **Table 2.** The mass of each is approximately 1,836 times greater than the mass of an electron. An electron's mass is so small that it is considered negligible when finding the mass of an atom.

If you were asked to estimate the height of your school building, you probably wouldn't give an answer in kilometers. The number would be too cumbersome to use. Considering the scale of the building, you would more likely give the height in a smaller unit, meters. When thinking about the small masses of atoms, scientists found that even grams were not small enough to use for measurement. Scientists need a unit that results in more manageable numbers. The unit of measurement used for atomic particles is the atomic mass unit (amu). The mass of a proton or a neutron is almost equal to 1 amu. This is not coincidence: the unit was defined that way. The atomic mass unit is defined as one-twelfth the mass of a carbon atom containing six protons and six neutrons. Remember that the mass of the carbon atom is contained almost entirely in the mass of the protons and neutrons that are located in the nucleus. Therefore, each of the 12 particles in the nucleus must have a mass nearly equal to 1 amu.



Where is the majority of the mass of an atom located?

Table 3 Mass Numbers of Some Atoms						
Element	Symbol	Atomic Number	Protons	Neutrons	Mass Number	Average Atomic Mass*
Boron	В	5	5	6	11	10.81 amu
Carbon	С	6	6	6	12	12.01 amu
0xygen	0	8	8	8	16	16.00 amu
Sodium	Na	11	11	12	23	22.99 amu
Copper	Cu	29	29	34	63	63.55 amu

<sup>\*</sup>The atomic mass units are rounded to two decimal places.

**Protons Identify an Element** You learned earlier that atoms of different elements are different because they have different numbers of protons. In fact, the number of protons tells you what type of atom you have and vice versa. For example, every carbon atom has six protons. Also, all atoms with six protons are carbon atoms. Atoms with eight protons are oxygen atoms. The number of protons in an atom is equal to a number called the **atomic number**. The atomic number of carbon is 6. Therefore, if you are given any one of the following—the name of the element, the number of protons in the element, or the atomic number of the element—you can determine the other two.



Which element is an atom with six protons in the nucleus?

**Mass Number** The mass number of an atom is the sum of the number of protons and the number of neutrons in the nucleus of the atom. Look at **Table 3** to see that this is true.

If you know the mass number and the atomic number of an atom, you can calculate the number of neutrons. The number of neutrons is equal to the atomic number subtracted from the mass number.

## number of neutrons = mass number - atomic number

Atoms of the same element with different numbers of neutrons can have different properties. For example, carbon with a mass number equal to 12, or carbon-12, is the most common form of carbon. Carbon-14 is present on Earth in much smaller quantities. Carbon-14 is radioactive, while carbon-12 is not.



Carbon Dating Living organisms on Earth contain carbon. Carbon-12 makes up 99 percent of this carbon. Carbon-13 and carbon-14 make up the other one percent. Which isotopes are archaeologists most interested in when they determine the age of carbon-containing remains? Explain your answer in your Science Journal.

# **Isotopes**

Not all the atoms of an element have the same number of neutrons. Atoms of the same element that have different numbers of neutrons are called **isotopes**. Suppose you have a sample of the element boron. Naturally occurring atoms of boron have mass numbers of 10 or 11. How many neutrons are in a boron atom? It depends upon the isotope of boron to which you are referring. Obtain the number of protons in boron from the periodic table. Then use the formula on the previous page to calculate the number of neutrons in each boron isotope. You can determine that boron can have five or six neutrons.



Uranium-238 has 92 protons. How many neutrons does it have?

# **Applying Science**

## How can radioactive isotopes help tell time?

toms can be used to measure the age of bones or rock formations that are millions of years old. The time it takes for half of the radioactive atoms in a piece of rock or bone to change into another element is called its half-life. Scientists use the half-lives of radioactive isotopes to measure geologic time.

Half-Lives of Radioactive Isotopes				
Radioactive Element	Changes to This Element	Half-Life		
Uranium-238	lead-206	4,460 million years		
Potassium-40	argon-40, calcium-40	1,260 million years		
Rubidium-87	strontium-87	48,800 million years		
Carbon-14	nitrogen-14	5,715 years		

## **Identifying the Problem**

The table above lists the half-lives of some radioactive isotopes and into which elements they change. For example, it would take 5,715 years for half of the carbon-14 atoms in a rock to change into atoms of nitrogen-14. After another 5,715 years, half of the remaining carbon-14 atoms will change, and so on. You can use these radioactive clocks to measure different periods of time.

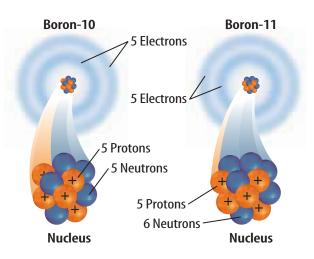
# **Solving the Problem**

- 1. How many years would it take half of the rubidium-87 atoms in a piece of rock to change into strontium-87? How many years would it take for 75 percent of the atoms to change?
- 2. After a long period, only 25 percent of the atoms in a rock remained uranium-238. How many years old would you predict the rock to be? The other 75 percent of the atoms are now which radioactive element?

Identifying Isotopes Models of two isotopes of boron are shown in Figure 7. Because the numbers of neutrons in the isotopes are different, the mass numbers are also different. You use the name of the element followed by the mass number of the isotope to identify each isotope: boron-10 and boron-11. Because most elements have more than one isotope, each element has an average atomic mass. The average atomic mass of an element is the weighted-average mass of the mixture of its isotopes. For example, four out of five atoms of boron are boron-11, and one out of five is boron-10. To find the weighted-average, or the average atomic mass of boron, you would use the following equation:

$$\frac{4}{5}(11 \text{ amu}) + \frac{1}{5}(10 \text{ amu}) = 10.8 \text{ amu}$$

The average atomic mass of the element boron is 10.8 amu. Note that the average atomic mass of boron is close to the mass of its most abundant isotope, boron-11.



**Figure 7** Boron-10 and boron-11 are two isotopes of boron. These two isotopes differ by one neutron. **Explain** why these atoms are

# section 🔑 review

#### **Summary**

#### **Atomic Mass**

- The nucleus contains most of the mass of an atom.
- The masses of a proton and neutron are approximately equal.
- The mass of an electron is considered negligible when finding the mass of an atom.
- The unit of measurement for atomic particles is the atomic mass unit (amu).
- The carbon-12 isotope was used to define the atomic mass unit.
- The number of protons identifies an element.

#### **Isotopes**

- Atoms of the same element with different numbers of neutrons are called isotopes.
- The average atomic mass of an element is the weighted-average mass of the mixture of isotopes.

#### **Self Check**

isotopes.

- **1. Identify** the mass number and atomic number of a chlorine atom that has 17 protons and 18 neutrons.
- **2. Explain** how the isotopes of an element are alike and how are they different.
- 3. Explain why the atomic mass of an element is an average mass.
- **4. Explain** how you would calculate the number of neutrons in potassium-40.
- 5. Think Critically Chlorine has an average atomic mass of 35.45 amu. The two naturally occurring isotopes of chlorine are chlorine-35 and chlorine-37. Why does this indicate that most chlorine atoms contain 18 neutrons?

## **Applying Math**

- **6. Use Numbers** If a hydrogen atom has two neutrons and one proton, what is its mass number?
- **7. Use Tables** Use the information in **Table 2** to find the mass in kilograms of each subatomic particle.

# **The Periodic Table**

# **Reading Guide**

# What You'll Learn

- Explain the composition of the periodic table.
- Use the periodic table to obtain information.
- **Explain** what the terms *metal*, *nonmetal*, and *metalloid* mean.

# Why It's Important

The periodic table is an organized list of the elements that compose all living and nonliving things known to exist in the universe.

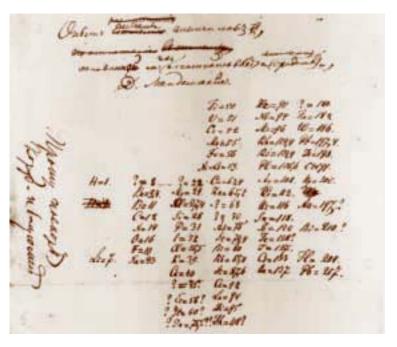
#### Review Vocabulary

**chemical property:** any characteristic of a substance that indicates whether it can undergo a certain chemical change

#### **New Vocabulary**

- periodic table
- group
- electron dot diagram
- period

# **Figure 8** Mendeleev discovered that the elements have a periodic pattern in their chemical properties.



# **Organizing the Elements**

On a clear evening, you can see one of the various phases of the Moon. Each month, the Moon seems to grow larger, then smaller, in a repeating pattern. This type of change is periodic. *Periodic* means "repeated in a pattern." The days of the week are periodic because they repeat themselves every seven days. The calendar is a periodic table of days and months.

In the late 1800s, Dmitri Mendeleev, a Russian chemist, searched for a way to organize the elements. When he arranged all the elements known at that time in order of increasing atomic masses, he discovered a pattern. **Figure 8** shows Mendeleev's early periodic chart. Chemical properties found in lighter elements could be shown to repeat in heavier elements. Because the pattern repeated, it was considered to be periodic. Today, this arrangement is called the periodic table of elements. In the periodic table, the elements are arranged by increasing atomic number and by changes in physical and chemical properties.

Table 4 Mendeleev's Predictions		
Predicted Properties of Ekasilicon (Es)	Actual Properties of Germanium (Ge)	
Existence Predicted: 1871	Actual Discovery: 1886	
Atomic mass = 72	Atomic mass = 72.61	
High melting point	Melting point = 938°C	
Density = $5.5 \text{ g/cm}^3$	Density = $5.323 \text{ g/cm}^3$	
Dark gray metal	Gray metal	
Density of EsO <sub>2</sub> = $4.7 \text{ g/cm}^3$	Density of $GeO_2 = 4.23 \text{ g/cm}^3$	

**Mendeleev's Predictions** Mendeleev had to leave blank spaces in his periodic table to keep the elements properly lined up according to their chemical properties. He looked at the properties and atomic masses of the elements surrounding these blank spaces. From this information, he was able to predict the properties and the mass numbers of new elements that had not yet been discovered. **Table 4** shows Mendeleev's predicted properties for germanium, which he called ekasilicon. His predictions proved to be accurate. Scientists later discovered these missing elements and found that their properties were extremely close to what Mendeleev had predicted.



Reading Check How did Mendeleev organize his periodic table?

**Improving the Periodic Table** Although Mendeleev's arrangement of elements was successful, it did need some changes. On Mendeleev's table, the atomic mass gradually increased from left to right. If you look at the modern periodic table, shown in **Table 5,** you will see several examples, such as cobalt and nickel, in which the mass decreases from left to right. You also might notice that the atomic number always increases from left to right. In 1913, the work of Henry G. J. Moseley, a young English scientist, led to the arrangement of elements based on their increasing atomic numbers instead of an arrangement based on atomic masses. This new arrangement seemed to correct the problems that had occurred in the old table. The current periodic table uses Moseley's arrangement of the elements.



Reading Check How is the modern periodic table arranged?



#### **Organizing a Personal Periodic Table**

#### **Procedure**

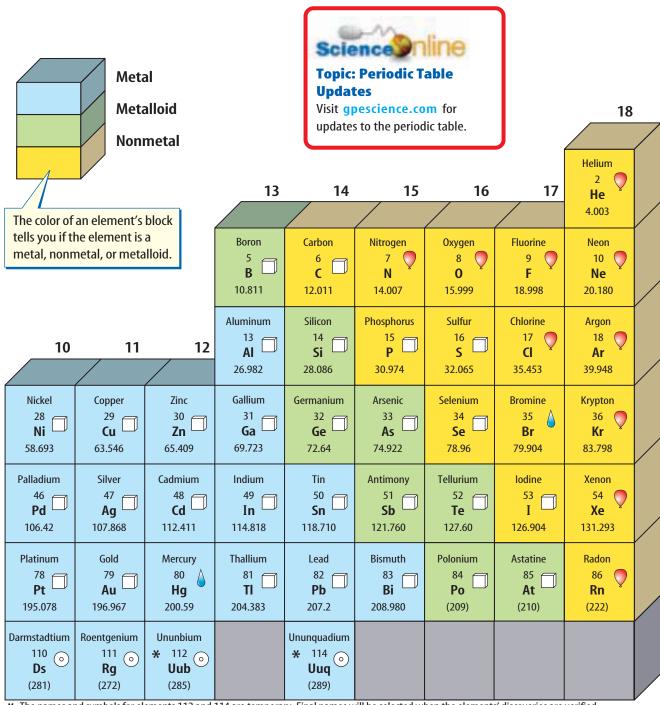


- 1. Complete the safety form.
- 2. Collect as many of the following items as you can find: feather, penny, container of water, pencil, dime, strand of hair, container of milk, container of orange juice, square of cotton cloth, nickel, crayon, quarter, container of soda, golf ball, sheet of paper, baseball, marble, leaf, paper clip.
- 3. Organize these items into several columns based on their similarities to create your own periodic table.

#### **Analysis**

- 1. Explain the system you used to group your items.
- 2. Were there any items on the list that did not fit into any of your columns?
- **3.** Infer how your activity modeled Mendeleev's work in developing the periodic table of the elements.

#### **Table 5** Periodic Table of the Elements Gas Columns of elements are called groups. Elements in the same group have similar chemical properties. Liquid 1 Solid Element -Hydrogen Hydrogen **Synthetic Atomic number** State of 2 1 matter Н Symbol 1.008 **Atomic mass** 1.008 The first three symbols tell you the state of matter of the element at room Lithium Beryllium temperature. The fourth symbol 2 identifies elements that are not present Li Be in significant amounts on Earth. Useful 9.012 6.941 amounts are made synthetically. Magnesium Sodium 12 11 5 7 8 9 3 3 4 6 Na Mg 22.990 24.305 Vanadium Potassium Calcium Scandium Titanium Chromium Manganese Iron Cobalt 19 20 21 22 23 24 25 26 27 4 K Sc Ti V Cr Ca Mn Fe Co 39.098 40.078 44.956 47.867 50.942 51.996 54.938 55.845 58.933 Rubidium Strontium Yttrium Zirconium Niobium Molybdenum **Technetium** Ruthenium Rhodium 43 (0) 38 39 40 44 45 37 5 Rb Sr Υ Zr Nb Mo Tc Ru Rh 88.906 92.906 95.94 (98)101.07 102.906 85.468 87.62 91.224 Cesium Barium Lanthanum Hafnium **Tantalum** Rhenium Iridium Tungsten **Osmium** 72 55 56 57 73 74 75 76 77 6 Hf W Cs Ba La Ta Re **0**s Ir 132.905 137.327 138.906 178.49 180.948 183.84 186.207 190.23 192.217 Rutherfordium Hassium Francium Radium Actinium Dubnium Seaborgium Bohrium Meitnerium 87 88 89 104 105 106 107 108 109 7 (0) Rf Fr Ra Ac Db Bh Hs Mt Sg (261)(223)(226)(227)(277)(268)(262)(266)(264)The number in parentheses is the mass number of the longest-lived isotope for that element. Rows of elements are called periods. Atomic number increases across a period. Cerium Praseodymium Neodymium Promethium Samarium 58 60 61 (0) 62 Lanthanide Ce Pr Nd Pm Sm series 150.36 140.116 140.908 144.24 (145)The arrow shows where these elements would fit into the Protactinium Uranium Neptunium Thorium Plutonium periodic table. They are moved 93 💿 90 ( 92 94 Actinide to the bottom of the table to Th Pa U Np Pu save space. series 232.038 231.036 238.029 (237)(244)



\* The names and symbols for elements 112 and 114 are temporary. Final names will be selected when the elements' discoveries are verified.

Europium 63 <b>Eu</b> 151.964	Gadolinium  64 <b>Gd</b> 157.25	Terbium  65 <b>Tb</b> 158.925	Dysprosium  66  Dy  162.500	Holmium 67 <b>Ho</b> 164.930	Erbium  68  Er  167.259	Thulium  69 <b>Tm</b> 168.934	Ytterbium  70 <b>Yb</b> 173.04	Lutetium 71 <b>Lu</b> 174.967	
Americium 95 Am (243)	Curium 96	Berkelium 97 o <b>Bk</b> (247)	Californium 98	Einsteinium 99 o Es (252)	Fermium 100	Mendelevium 101  Md (258)	Nobelium 102	Lawrencium 103  Lr (262)	



Research Physicist The study of nuclear interactions is shared by chemists and physicists. Research physicists use their knowledge of the physical laws of nature to explain the behavior of the atom and its composition. Explain in your Science Journal why physicists would study the amount of energy that electrons contain.

**Figure 9** Energy levels in atoms can be represented by a flight of stairs. Each stair step away from the nucleus represents an increase in the amount of energy within the electrons.

**Explain** what determines the chemical properties of an element.

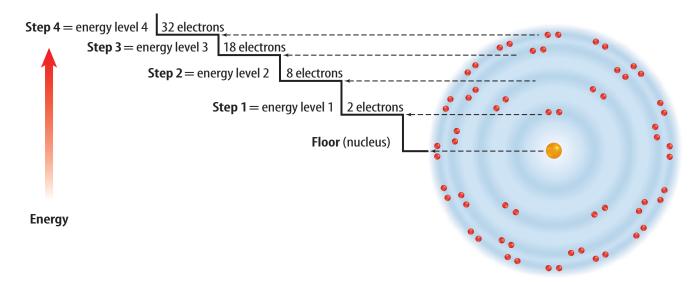
#### The Atom and the Periodic Table

Objects often are sorted or classified according to the properties they have in common. This also is done in the periodic table. The vertical columns in the periodic table are called **groups**, or families, and are numbered 1 through 18. Elements in each group have similar properties. For example, in Group 11, copper, silver, and gold have similar properties. Each is a shiny metal and a good conductor of electricity and heat. What is responsible for the similar properties? To answer this question, look at the structure of the atom.

**Electron Cloud Structure** You have learned about the number and location of protons and neutrons in an atom. But where are the electrons located? How many are there? In a neutral atom, the number of electrons is equal to the number of protons. Therefore, a carbon atom, with an atomic number of 6, has six protons and six electrons. These electrons are located in the electron cloud surrounding the nucleus.

Scientists have found that electrons within the electron cloud have different amounts of energy. Scientists model the energy differences of the electrons by placing the electrons in energy levels, as in **Figure 9.** Energy levels nearer the nucleus have lower energy than those levels that are farther away. Electrons fill these energy levels from the inner levels (closer to the nucleus) to the outer levels (farther from the nucleus).

Elements that are in the same group have the same number of electrons in their outer energy levels. It is the number of electrons in the outer energy level that determines the chemical properties of an element. It is important to understand the link between the location on the periodic table, chemical properties, and the structure of the atom.



**Energy Levels** Energy levels are named using the numbers one to seven. The maximum number of electrons that can be contained in each of the first four levels is shown in **Figure 9.** For example, energy level one can contain a maximum of two electrons. Energy level two can contain a maximum of eight electrons. Notice that energy levels three and four contain several electrons. A complete and stable outer energy level will contain eight electrons. In elements in periods three and higher, additional electrons can be added to inner energy levels, although the outer energy level contains only eight electrons.

**Rows on the Table** Remember that an atomic number found on the periodic table is equal to the number of electrons in an atom. Look at **Figure 10.** The first row has hydrogen with one electron and helium with two electrons both in energy level one. Because energy level one is the outermost level containing an electron, hydrogen has one outer electron. Helium has two outer electrons. Recall from **Figure 9** that energy level one can hold only two electrons. Therefore, helium has a full or complete outer energy level.

The second row begins with lithium, which has three electrons, two in energy level one and one in energy level two. Lithium has one outer electron. Lithium is followed by beryllium, with two outer electrons, boron with three, and so on until you reach neon, with eight outer electrons. Again, looking at Figure 9, energy level two can hold only eight electrons. Therefore, neon has a complete outer energy level. Do you notice how the row in the periodic table ends when an outer energy level is filled? In the third row of elements, the electrons begin filling energy level three. The row ends with argon, which has a full outer energy level of eight electrons.



How many electrons are needed to fill the outer energy level of sulfur?



# **Topic: Atomic Energy Level**

Visit **gpescience.com** for Web links to information about the structure of atomic energy levels.

**Activity** Draw a diagram that details how the energy levels are structured.

**Figure 10** One proton and one electron are added to each element as you go across a period in the periodic table.

**Explain** what the elements in the last column share in relation to their outer energy levels.

Helium

Hydrogen 1 <b>H</b>	
Lithium	Beryllium
3	4
<b>Li</b>	<b>Be</b>
Sodium	Magnesium
11	12
<b>Na</b>	<b>Mg</b>

					He
Boron	Carbon	Nitrogen	Oxygen	Fluorine	Neon
5	6	7	8	9	10
<b>B</b>	<b>C</b>	<b>N</b>	<b>O</b>	<b>F</b>	<b>Ne</b>
Aluminum	Silicon	Phosphorus	Sulfur	Chlorine	Argon
13	14	15	16	17	18
<b>Al</b>	<b>Si</b>	<b>P</b>	<b>S</b>	Cl	<b>Ar</b>

**Figure 11** The elements in Group 1 have one electron in their outer energy level. This electron dot diagram represents that one electron.

**Explain** why the outer electrons of an element are important.

Н٠

li۰

Na<sup>•</sup>

**K**•

Rb.

Figure 12 Electron dot diagrams show the electrons in an element's outer energy level.



The electron dot diagram for Group 17 consists of three sets of paired dots and one single dot.

**Electron Dot Diagrams** Did you notice that hydrogen, lithium, and sodium each have one electron in their outer energy levels? Elements that are in the same group have the same number of electrons in their outer energy levels. These outer electrons are so important in determining the chemical properties of an element that a special way to represent them has been developed. American chemist G. N. Lewis created this method while teaching a college chemistry class. An electron dot diagram uses the symbol of the element and dots to represent the electrons in the outer energy level. **Figure 11** shows the electron dot diagram for Group 1 elements. The electron configuration of an atom determines how that atom reacts with other atoms. Electron dot diagrams also are used to show how the electrons in the outer energy levels are bonded when elements combine to form compounds.

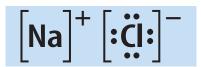
**Same Group, Similar Properties** The elements in Group 17, the halogens, have electron dot diagrams similar to chlorine, shown in **Figure 12.** All halogens have seven electrons in their outer energy levels. Because all of the members of a group on the periodic table have the same number of electrons in their outer energy levels, group members will undergo chemical reactions in similar ways.

A common property of the halogens is the ability to form compounds readily with elements in Group 1. Group 1 elements each have only one electron in their outer energy levels. **Figure 12** shows an example of a compound formed by one such reaction. The Group 1 element, sodium, reacts easily with the Group 17 element, chlorine. The result is the compound sodium chloride, or NaCl, ordinary table salt.

Not all elements will combine readily with other elements. The elements in Group 18 have complete outer energy levels. This special configuration makes Group 18 elements relatively unreactive. You will learn more about why and how bonds form between elements in later chapters.



Why do elements in a group undergo similar chemical reactions?



Sodium combines with chlorine to give each element a complete outer energy level in the resulting compound.



Neon, a member of Group 18, has a full outer energy level. Neon has eight electrons in its outer energy level, making it unreactive.

## **Regions on the Periodic Table**

The periodic table has several regions with specific names. The horizontal rows of elements on the periodic table are called **periods.** The elements increase by one proton and one electron as you go from left to right in a period.

All of the elements in the blue squares in **Figure 13** are metals. Iron, zinc, and copper are examples of metals. Most metals exist as solids at room temperature. They are shiny, can be drawn into wires, can be pounded into sheets, and are good conductors of heat and electricity.

Those elements on the right side of the periodic table, in yellow, are classified as nonmetals. Oxygen, bromine, and carbon are examples of nonmetals. Most nonmetals are gases, are brittle, and are poor conductors of heat and electricity at room temperature. The elements in green are metalloids or semimetals. They have some properties of both metals and nonmetals. Boron and silicon are examples of metalloids.

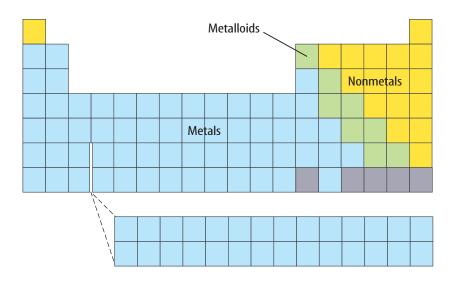


What are the properties of the elements located on the left side of the periodic table?

A Growing Family Scientists around the world are continuing their research into the synthesis of elements. In 1994, scientists at the Heavy-Ion Research Laboratory in Darmstadt, Germany, discovered element 111. As of 1998, only one isotope of element 111 had been found. This isotope had a life span of 0.002 s. In 1996, element 112 was discovered at the same laboratory. As of 1998, only one isotope of element 112 had been found. The life span of this isotope was 0.00048 s. Both of these elements are produced in the laboratory by joining smaller atoms into a single atom. The search for elements with higher

atomic numbers continues. Scientists think they have synthesized elements 114 and 116. However, the discovery of these elements has not yet been confirmed.

Figure 13 Metalloids are located along the green stair-step line. Metals are located to the left of the metalloids. Nonmetals are located to the right of the metalloids.





#### **Topic: New Elements**

Visit gpescience.com for Web links to information about newly synthesized elements.

**Activity** Write an article explaining how several new elements were synthesized and who synthesized them.



**Figure 14** Scientists think that some elements are found in nature only within stars.

#### **Elements in the Universe**

Using the technology that is available today, scientists are finding the same elements throughout the universe. They have been able to study only a small portion of the universe because it is so vast. Many scientists believe that hydrogen and helium are the building blocks of other elements. Atoms join together within stars to produce elements with atomic numbers greater than 1 or 2, the atomic numbers of hydrogen and helium. Exploding stars, or supernovas, shown in Figure 14, give scientists evidence to support this theory. When stars reach the supernova stage, which is characterized by a massive explosion, a mixture of elements, including the heavy elements such as iron, are flung into the galaxy. Many scientists believe that supernovas have spread the elements that are found throughout the universe. Some of these elements are found only in trace amounts in Earth's crust as a result of uranium decay. Others have been found only in stars.

## section

# review

#### **Summary**

#### **Organizing the Elements**

- Mendeleev organized the elements using increasing atomic mass and chemical and physical properties.
- Mendeleev left blank spaces in his table to allow for elements that were yet undiscovered.
- Moseley corrected the problems in the periodic table by arranging the elements in order of increasing atomic number.

#### The Atom and the Periodic Table

- The vertical columns in the periodic table are known as groups or families. Elements in a group have similar properties.
- Electrons within the electron cloud have different amounts of energy.

#### **Regions of the Periodic Table**

- The periodic table is divided into these regions: periods, metals, nonmetals, and metalloids.
- Scientists around the world continue to try to synthesize new elements.

#### **Self Check**

- 1. Identify Use the periodic table to find the name, atomic number, and average atomic mass of the following elements: N, Ca, Kr, and W.
- **2. List** the period and group in which each of these elements is found: nitrogen, sodium, iodine, and mercury.
- 3. Classify each of these elements as a metal, a nonmetal, or a metalloid and give the full name of each: K, Si, Ba, and S.
- 4. Think Critically The Mendeleev and Mosely periodic tables have gaps for the as-then-undiscovered elements. Why do you think the table used by Mosely was more accurate at predicting where new elements would be placed?

#### **Applying Math**

5. Make a Graph Construct a circle graph showing the percentage of elements classified as metals, metalloids, and nonmetals. Use markers or colored pencils to distinguish clearly between each section on the graph. Record your calculations in your Science Journal.



# A Periodic Table of Foods

#### Real-World Problem –

Mendeleev's task of organizing a collection of loosely related items probably seemed daunting at first. How will using your favorite foods to create your own periodic table be similar to the task that Mendeleev had?

#### Goals

- Organize 20 of your favorite foods into a periodic table of foods.
- Analyze and evaluate your periodic table for similar characteristics among groups or family members on your table.
- **Infer** where new foods would be placed on your table.

#### **Materials**

11 × 17-in paper 12- or 18-in ruler colored pencils or markers

#### Safety Precautions 🗪 🛂 🔙

#### Procedure -

- **1.** Complete the safety form before you begin.
- **2. List** 20 of your favorite foods and drinks.
- **3. Describe** basic characteristics of each food and drink item. For example, you might describe the primary ingredient, nutritional value, taste, and color or identify the food group of each item.
- **4. Create** a data table to organize the information that you collect.
- 5. Using your data table, construct a periodic table of foods. Determine which characteristics you will use to group your items. Create families (columns) of food and drink items that share similar characteristics.



For example, potato chips, pretzels, and crackers could be combined into a family of salty tasting foods. Create as many groups as you need. You do not need to have the same number of items in every family.

# Conclude and Apply-

- 1. Evaluate the characteristics you used to make the groups on your periodic table. Do the characteristics of each group adequately describe all the family members? Do the characteristics of each group distinguish its family members from the family members of the other groups?
- **2. Analyze** the reasons why some items did not fit easily into a group.
- Infer why chemists have not created a periodic table of compounds.



Construct a bulletin board of the periodic tables of foods created by the class.
Compare and contrast the tables.



# **Use the Internet**

# What's in a name?

#### Goals

- Research the names and symbols of various elements.
- Study the methods that are used to name elements and how they have changed through time.
- **Organize** your data by making your own periodic table.
- **Study** the history of certain elements and their discoveries.
- **Create** a table of your findings and communicate them to other students.

#### **Data Source Internet Lab**

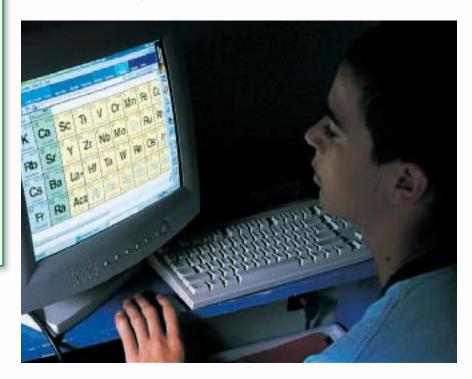
Visit **gpescience.com** for more information about naming elements, elements' symbols, and the discovery of new elements, and for data collected by other students.

#### Real-World Problem

The symbols used for different elements sometimes are easy to figure out. After all, it makes sense for the symbol for carbon to be C and the symbol for nitrogen to be N. However, some symbols aren't as easy to figure out. For example, the element silver has the symbol Ag. This symbol comes from the Latin word for silver, argentum. How are symbols and names chosen for elements?

#### Make a Plan

- **1.** Make a list of particular elements you wish to study.
- **2. Identify** the symbols for these elements.
- **3. Research** the discovery of these elements. Do their names match their symbols? Were they named after a property of the element, a person, their place of discovery, or a system of nomenclature? What was that system?



# Using Scientific Methods

#### Follow Your Plan

- Make sure your teacher approves your plan before you start.
- **2.** Visit the Web site provided for links to different sites about elements, their history, and how they were named.
- 3. **Research** these elements.
- **4.** Carefully record your data in your Science Journal.



# Analyze Your Data

- **1. Record** in your Science Journal how the symbols for your elements were chosen. What were your elements named after?
- **2. Construct** an element key that includes the research information that you found for your elements.
- **3.** Make a chart of your class's findings. Sort the chart by year of discovery for each element.
- **4.** How are the names and symbols for newly discovered elements chosen? Make a chart that shows how the newly discovered elements will be named.

# Conclude and Apply

- 1. Compare your findings to those of your classmates. Did anyone's data differ for the same element? Were all the elements in the periodic table covered?
- **2. Explain** the system that is used to name the newly discovered elements today.
- **3. Explain** Some elements were assigned symbols based on their name in another language. Do these examples occur for elements discovered today or long ago?



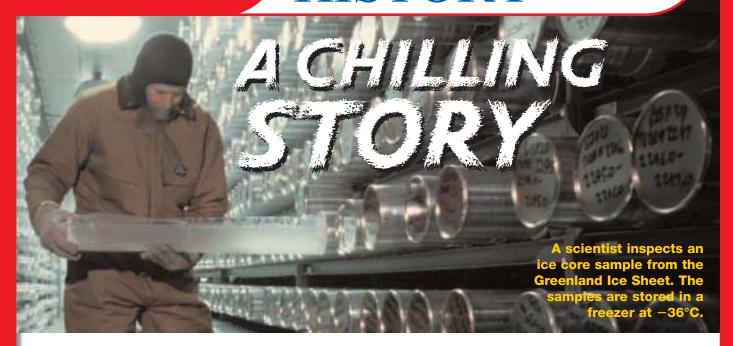
Find this lab using the link below. Post your data in the table provided. **Compare** your data to those of other students.

Internet Lab gpescience.com

# TIME

# SCIENCE AND HISTORY

SCIENCE CAN CHANGE THE COURSE OF HISTORY!



icture this: It's 1361. A ship from Norway arrives at a Norwegian settlement in Greenland. The ship's crew members hope to trade its cargo with the people living there. The crew members get off the ship. They look around. The settlement is deserted. More than 1,000 people had vanished!

New evidence has shed some light on the mysterious disappearance of the Norse settlers. The evidence came from a place on the Greenland Ice Sheet over 600 km away from the settlement. This part of Greenland is so cold that snow never melts. As new snow falls, the existing snow is buried and

turns to ice.

By drilling deep into this ice, scientists can

Air bubbles and dirt trapped in ice provide clues to Earth's past climate. recover an ice core. The core is made up of ice formed from snowfalls way, way back in time.

By measuring the ratio of oxygen isotopes in the ice core, scientists can estimate Greenland's past air temperatures. The cores provide a detailed climate history going back over 80,000 years. Individual ice layers can be dated much like tree rings to determine their ages. The air bubbles trapped within each layer are used to learn about climate variations. Dust and pollen trapped in the ice also yield clues to ancient climates.

## A Little Ice Age

Based on their analysis, scientists think the Norse settlers moved to Greenland during an unusually warm period. Then, in the 1300s, the climate started to cool and a period known as the Little Ice Age began. The ways the Norse people hunted and farmed were inadequate for survival in this long chill. Because they couldn't adapt to their colder surroundings, the settlers died out.

provide clues to Earth's past climat

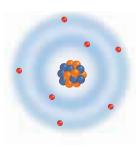
Research Report Evidence seems to show that Earth is warming. Rising temperatures could affect our lives. Research global warming to find out how Earth may change. Share your report with the class.



#### **Reviewing Main Ideas**

#### Section 1 Structure of the Atom

- **1.** A chemical symbol is a shorthand way of writing the name of an element.
- 2. An atom consists of a nucleus made up of protons and neutrons surrounded by an electron cloud, as shown in the figure to the right.



- **3.** Quarks are particles of matter that make up protons and neutrons.
- **4.** The model of the atom changes over time. As new information is discovered, scientists incorporate it into the model.

#### Section 2 Masses of Atoms

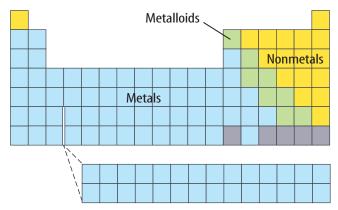
- **1.** The number of neutrons in an atom can be computed by subtracting the atomic number from the mass number.
- **2.** The isotopes of an element are atoms of the same element that have different numbers of neutrons. The figure below shows the isotopes of hydrogen.



**3.** The average atomic mass of an element is the weighted-average mass of the mixture of its isotopes. Isotopes are named by using the element name, followed by a dash, and its mass number.

#### Section 3 The Periodic Table

- **1.** In the periodic table, the elements are arranged by increasing atomic number, resulting in periodic changes in properties. Knowing that the number of protons, electrons, and atomic number are equal gives you a partial composition of an atom.
- 2. In the periodic table, the elements are arranged in 18 vertical columns, or groups, and seven horizontal rows, or periods.
- **3.** Metals are found at the left of the periodic table, nonmetals at the right, and metalloids along the line that separates the metals from the nonmetals, as shown below.



**4.** Elements are placed on the periodic table in order of increasing atomic number. A new row on the periodic table begins when the outer energy level of an element is filled.

FOLDABLES Use the Foldable that you made at the beginning of the chapter to help you review properties of atoms and the periodic table.

## **Using Vocabulary**

atom p. 579	mass number p. 585
atomic number p. 585	neutron p. 579
average atomic mass p. 587	nucleus p. 579
electron p. 579	period p. 595
electron cloud p. 583	periodic table p. 588
electron dot diagram p. 594	proton p. 579
group p. 592	quark p. 579
isotope p. 586	

Complete the statement with the correct vocabulary word or phrase.

- **1.** Mendeleev created an organized table of elements called the \_\_\_\_\_\_.
- **2.** Two elements with the same number of protons but a different number of neutrons are called \_\_\_\_\_\_.
- **3.** \_\_\_\_\_ is the weighted-average mass of all the known isotopes for an element.
- **4.** The positively charged center of an atom is called the \_\_\_\_\_.
- **5.** The particles that make up protons and neutrons are called \_\_\_\_\_.
- **6.** A(n) \_\_\_\_\_\_ is a horizontal row in the periodic table.
- **7.** The \_\_\_\_\_\_ is the sum of the number of protons and neutrons in an atom.
- **8.** In the current model of the atom, the electrons are located in the \_\_\_\_\_\_.

#### **Checking Concepts**

Choose the word or phrase that best answers the question.

- **9.** In which state of matter are most of the elements to the left of the stair-step line in the periodic table?
  - A) gas
- **c)** plasma
- **B)** liquid
- **D)** solid

- **10.** Which term describes a pattern that repeats?
  - A) isotopic
- c) periodic
- B) metallic
- **D)** transition
- **11.** Which element has similar properties to those of neon?
  - **A)** aluminum
- c) arsenic
- B) argon
- **D)** silver
- **12.** Which term describes boron?
  - A) metal
- c) noble gas
- **B)** metalloid
- **D)** nonmetal
- **13.** How many outer-level electrons do lithium and potassium have?
  - A) one
- **C)** three
- **B)** two
- **D)** four
- **14.** Which is **NOT** found in the nucleus of an atom?
  - A) electron
- **c)** proton
- **B)** neutron
- **D)** quark
- **15.** The atomic number of rhenium is 75. The atomic mass of one of its isotopes is 186. How many neutrons are in an atom of this isotope?
  - **A)** 75
- **C)** 186
- **B)** 111
- **D)** 261

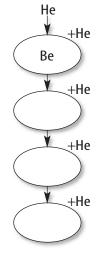
Use the photo below to answer question 16.



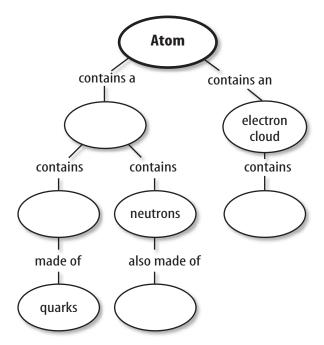
- **16.** Which scientist developed this atomic model?
  - A) Bohr
- **c)** Rutherford
- **B)** Dalton
- **D)** Thomson

#### **Interpreting Graphics**

- **17.** Construct As a star dies, it becomes more dense. Its temperature rises to a point at
  - which He nuclei are combined with other nuclei. When this happens, the atomic numbers of the other nuclei are increased by 2 because each gains the two protons contained in the He nucleus. For example, Cr fuses with He to become Fe. Copy and complete the concept map showing the first four steps in He fusion.



**18.** Copy and complete the concept map below.



#### **Thinking Critically**

**19. Infer** Lead and mercury are two pollutants in the environment. From information about them in the periodic table, determine why they are called heavy metals.

- **20. Explain** why it is necessary to change models as new information becomes available.
- **21.** Infer Why did scientists choose carbon as a base for the atomic mass unit? Which isotope of carbon did they use?
- **22. Infer** Ge and Si are used in making semiconductors. Are these two elements in the same group or the same period?
- 23. Explain Using the periodic table, predict how many outer level electrons will be in elements 114, 116, and 118. Explain your answer.
- **24. Infer** Ca is used by the body to make bones and teeth. Sr-90 is radioactive. Ca is safe for people, and Sr-90 is hazardous. Why is Sr-90 hazardous to people?

#### **Applying Math**

**25.** Solve One-Step Equations The atomic number of yttrium is 39. The atomic mass of one of its isotopes is 89. How many neutrons are in an atom of this isotope?

Use the table below to answer question 26.

Electrons per Energy Level			
Energy Level	Maximum Number of Electrons		
1	2		
2	Do not write in		
3	this book.		
4			

**26.** Use Tables Use the information in Figure 9 to determine how many electrons should be in the second, third, and fourth energy levels for argon, atomic number 18. Copy and complete the table above with the number of electrons for each energy level.

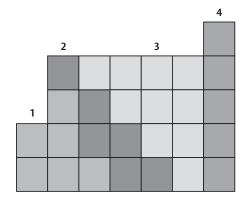
# chapter Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### Multiple Choice

- **1.** Which group of elements on the periodic table do not combine readily with other elements?
  - **A.** Group 1
  - **B.** Group 2
  - **C.** Group 17
  - **D.** Group 18

Use the illustration below to answer question 2.



- **2.** Which of the regions shown on the periodic table contains mostly elements that are gases at room temperature?
  - **A.** region 1
  - **B.** region 2
  - **c.** region 3
  - **D.** region 4

#### **Test-Taking Tip**

**Have Breakfast** The morning of the test, eat a healthy breakfast with a balanced amount of protein and carbohydrates.

- **3.** Which scientist proposed the idea that atoms make up all substances?
  - A. Aristotle
  - B. Dalton
  - **c.** Democritus
  - **D.** Galileo

Use the table below to answer question 4.

Element	Electrons in a Neutral Atom	Electrons in Outer Energy Level
Carbon	6	4
Oxygen	8	6
Neon	10	8
Sodium	11	1
Chlorine	17	7

- **4.** Which element would you expect to be located in Group 1 of the periodic table?
  - A. oxygen
  - B. neon
  - **c.** sodium
  - **D.** chlorine
- **5.** The element nickel has five naturally occurring isotopes. Which of the following describes the relationship of these isotopes?
  - **A.** same mass, same atomic number
  - B. same mass, different atomic number
  - **c.** different mass, same atomic number
  - **D.** different mass, different atomic number

- **6.** Atoms of different elements are different because they have different numbers of what type of particle?
  - A. electrons
  - **B.** photons
  - C. protons
  - **D.** neutrons

#### **Gridded Response**

- **7.** According to the periodic table, an atom of lead has an atomic number of 82. How many neutrons does lead-207 have?
- **8.** About three out of four chlorine atoms are chlorine-35, and about one out of four is chlorine-37. What is the average atomic mass of chlorine?



Use the illustration below to answer question 9.

$$\left[ \mathsf{Na} \right]^+ \left[ \vdots \ddot{\mathsf{C}} \vdots \right]^-$$

- **9.** The electron dot diagram above shows how a sodium atom, Na, combines with a chlorine atom, Cl, to form sodium chloride. What do the + and the - symbols indicate in the diagram?
- **10.** Why isn't the mass of the electron included in the mass of an atom on the periodic table?

#### Extended Response

Use the illustration below to answer questions 11 and 12.



- 11. The illustration above shows the currently accepted model of atomic structure. Describe this model.
- **12.** Compare and contrast the model shown above with Bohr's model of an atom.
- **13.** How can you use the periodic table to determine the average number of neutrons an element has, even though the number of neutrons is not listed?
- **14.** Describe how Dalton's modernization of the ancient Greeks' ideas of elements, atoms, and compounds provided a basis for understanding chemical reactions. Give an example.

# chapter

# 20

#### BIG (Idea

Processes in Earth continually change rocks from one type into another.

#### **20.1 Minerals**

MAIN (Idea A mineral is a naturally occurring material that is inorganic and crystalline.

#### **20.2 Igneous Rocks**

MAIN (Idea Igneous rocks form when molten magma cools and becomes solid.

#### **20.3 Sedimentary Rocks**

MAIN (Idea Sedimentary rocks are formed from particles of rock and other materials bonded together.

# 20.4 Metamorphic Rocks and the Rock Cycle

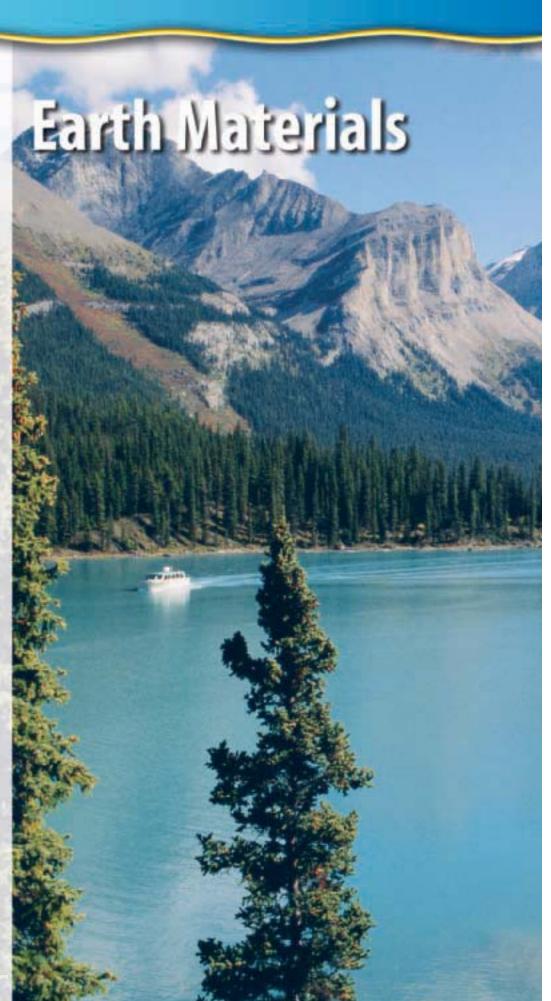
MAIN (Idea Metamorphic rocks form when existing rocks are changed by heat and pressure.

#### Walking on Air

We often think of oxygen as being in the air we breathe, but we also walk on it every day. By weight, almost half of Earth's crust is oxygen. Even these mountains in the Canadian Rockies are made mostly of oxygen.

#### **Science Journal**

In your Science Journal, list five materials and where you think these materials came from.



# **Start-Up Activities**



# Earth Materials at Home and School

You come in contact with Earth materials every day. Many of the objects around you are Earth materials, or items processed using minerals or rocks as raw materials.

- 1. Obtain several items from your teacher.
- 2. Make a three-column table on a separate sheet of paper.
- 3. In the first column, list each item.
- 4. In the second column, decide whether each item listed is a natural Earth material or a product made from Earth materials.
- In the third column, indicate whether the item is found at home, school, or both places.
- 6. Think Critically Select three of the items in your first column and imagine that they no longer exist. Explain how you could cope without these materials. What other materials could be used instead?



Preview this chapter's content and activities at gpescience.com



**Textures** Make the following Foldable to help you organize the types of textures in igneous, sedimentary, and metamorphic rocks.

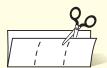
Fold a sheet of paper in half lengthwise. Make the back edge about 2 inches longer than the front edge.



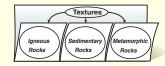
**STEP 2 Turn** the paper so the fold is on the bottom. Then **fold** it into thirds.



STEP 3 Unfold and cut only the top layer along both folds to make three tabs.



STEP 4 Label the Foldable as shown



**Making a Concept Map** As you read the chapter, write about and illustrate the texture types shown by each group of rocks represented in your concept map.

# **Minerals**

## **Reading Guide**

#### What You'll Learn

- **Describe** characteristics of all minerals.
- Identify common minerals using physical properties.
- Compare and contrast some conditions of mineral formation.

# Why It's Important

Minerals are a source of raw materials used to support civilization.

#### Review Vocabulary

ionic bond: attraction formed between oppositely charged ions in an ionic compound

#### **New Vocabulary**

- mineral
- cleavage
- fracture
- hardness
- streak
- magma

#### **Common Elements**

Take a look at the periodic table of elements. Of the first 92 elements, 90 are found in Earth, and of these, only a small number combine to make up most of the common minerals in Earth's crust. **Table 1** lists these important elements. Most of the chemical formulas of common minerals contain some of these elements.

**Composition of Earth's Crust** The crust is the outermost layer of Earth. It includes all continental material and the material that forms the ocean bottom. The crust extends down tens of kilometers beneath the continents, but it is much thinner where it makes up the ocean bottom and material below, as shown in **Figure 1.** 

Table 1 Major Elements in Earth's Crust					
Element	Percent (by mass)	Element Percent (by mass)			
Oxygen	46.6%	Sodium	2.8%		
Silicon	27.7%	Potassium	2.6%		
Aluminum	8.1%	Magnesium	2.1%		
Iron	5.0%	All others	1.5%		
Calcium	3.6%				

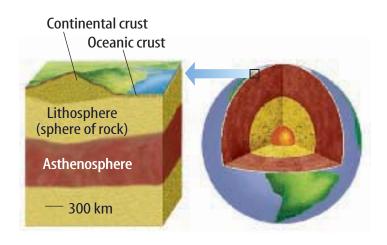
**Chemical Element Building Blocks** Imagine Earth's chemical parts being like a set of interlocking blocks. In the set you are given lots of common types of blocks from which you can make thousands of forms. But, you are given only a few of the special blocks. The bulk of the forms you build consist of the common blocks. Elements and minerals in Earth's crust are a lot like the block set. For example, most minerals of the crust, whether beneath the land surface or ocean water, contain abundant oxygen and silicon.

#### What's a mineral?

Remember that atoms of different elements can bond chemically to form compounds. A mineral is a naturally occurring element or compound that is inorganic, solid, and has a crystalline structure. *Inorganic* means that minerals are materials that are not produced by living organisms. The composition of minerals are indicated by their chemical formulas. For example, the element gold is a mineral with the chemical formula Au. Similarly, fluorite is a mineral that contains Ca and F in a 1:2 ratio, resulting in the chemical formula CaF<sub>2</sub>.

## **Physical Properties**

A mineral has a particular chemical composition. However, sometimes the chemical composition of a mineral can vary slightly due to the presence of small amounts of chemical impurities. These impurities can cause some of the mineral's physical properties to vary. For example, the gemstones ruby and sapphire are both the mineral corundum, even though they have different colors. A ruby is red because it contains more of the element chromium than a sapphire, which is blue. Different amounts of the chemical impurity chromium in the crystalline structure of corundum cause the difference in color.



**Figure 1** The crust and a thin layer of the upper mantle make up the lithosphere. The lithosphere floats on a dense, plasticlike layer called the asthenosphere.



**Figure 2** Because mica has one direction of cleavage, it can be separated in layers.

**Atom Arrangement** Some physical properties are controlled by the orderly arrangement of atoms in a mineral's structure. This orderly pattern is what makes a mineral crystalline. The arrangement of atoms and the bonds between them can reflect the way a mineral breaks, how hard it is, and what type of crystal shape it has.

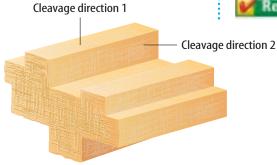
**How Minerals Break** When minerals break along planes that cut across relatively weak chemical bonds, a smooth, flat surface is created. The ability of a mineral to do this is the physical property called **cleavage**. All parallel cleavage planes define a single direction of cleavage. The mica family of minerals exhibits only one direction of cleavage, as shown in **Figure 2**. Other minerals may show two or more different directions of cleavage, as in **Figure 3**. If this happens, those different planar directions have to meet each other at an angle.

Some minerals do not split along well-defined flat surfaces. In such cases, a mineral will break unevenly. This type of irregular break is called **fracture**. Quartz is an example of a common mineral that does not cleave, but exhibits fracture. This physical property helps to distinguish quartz from other minerals.

**Figure 3** Feldspar is an example of a mineral with two planes of cleavage.



Reading Check What distinguishes quartz from other minerals?



**610 CHAPTER 20** Earth Materials

**Hardness** Bonds connecting atoms in materials often have different strengths. When you scratch a mineral with another material the scratch forms as bonds in the mineral are broken. The physical property that measures resistance to scratching is called **hardness**. You can compare the hardness of different materials by applying scratch tests and using Mohs Scale, as shown in **Table 2.** When a hardness test is performed by rubbing two objects together, the softer of the two will wear away.

Table 2 Mohs Scale of Hardness				
1. Talc	6. Feldspar			
2. Gypsum (fingernail 2.2)	7. Quartz (streak plate 7.0)			
3. Calcite (copper penny 3.2)	8. Topaz			
4. Fluorite	9. Corundum			
5. Apatite (glass plate 5.5)	10. Diamond			

Today, you might be using a pencil that takes advantage of the softness of a mineral. The graphite in the core of some pencils has one plane of cleavage and very weak bonds between carbon atoms. The weak bonds make the graphite soft. As you write with the pencil, thin plates of graphite are left on your paper.

Luster and Streak The way a mineral reflects light is the physical property known as luster. Two main types of luster, metallic and nonmetallic, help subdivide minerals and often give a clue about their compositions. Just as you might guess, metallic luster minerals reflect light in a way that a metal surface might, such as the shiny chrome on a car or bicycle. Nonmetallic luster, shown in Figure 4, includes descriptions of all other types, such as those minerals that shine like glass or appear earthy or waxy.

The color of a mineral in powdered form is called **streak**. The streak of a mineral may be the same color as the mineral specimen. When a mineral shows different colors, the streak powder color generally stays the same, which helps identify the mineral. A streak test is performed by rubbing a mineral on an unglazed, white porcelain tile.

**Figure 4** The mineral on the left produces a glassy luster; the mineral on the right produces a metallic luster.







# Identifying Salt's Crystal System

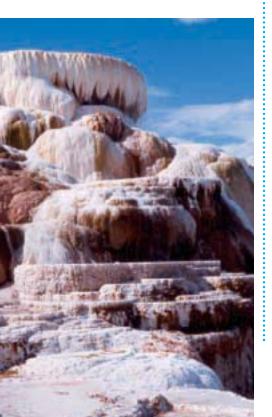
#### **Procedure**

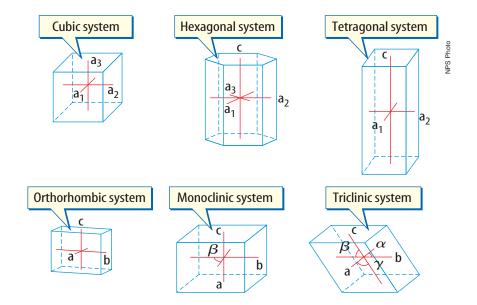
- Sprinkle a small quantity of salt onto a dark surface.
- 2. Using a magnifying lens, observe the individual grains of salt.

#### **Analysis**

- Make a sketch showing the shapes of several salt grains.
- 2. Why are some of the grains more elongated than others?
- 3. To which crystal system does salt belong? Support your answer with details from the text.

**Figure 6** Hydrothermal minerals form on the rims of hot springs.





**Figure 5** Minerals can be classified using six basic crystal forms.

**Crystal Shape** The orderly internal arrangement of atoms in a mineral often is related to its external crystal shape. In fact, some minerals take on a geometric shape that is a larger version of their internal atomic arrangement. Even though many unique shapes are exhibited by mineral crystals in nature, each can be sorted into one of the six crystal systems, as shown in **Figure 5.** The types of symmetry shown by the crystal are key elements in determining the crystal system to which a mineral belongs.

#### **Mineral Formation**

A mineral crystal grows as atoms are added to its surfaces, edges, or corners. The types of atoms that are added depend on the atoms in the growing crystal's surroundings. Growth also is controlled by how fast atoms can migrate to the crystal and by the temperature and pressure of the surroundings. Mineral crystals can form in different ways. One way is by precipitation from hot, water-rich fluids. Another way is by solidification from molten rock. A third way is by the evaporation of water rich in dissolved salts at low temperatures near Earth's surface.

Minerals from Hot Water Some minerals are produced from hot-water solutions containing dissolved mineral matter. You know that sugar dissolves fastest in hot water. As hot water cools, its atoms slow down and atoms of dissolved material are able to form chemical bonds. Minerals often form around the edges of hot springs, as shown in **Figure 6.** When hot water passes through cracks in cooler rock, minerals may form within the cracks. The cracks become lined and filled with mineral matter. Sometimes, veins or halos of concentrated minerals like gold, silver, or copper are produced in fractures.

Minerals from Magma Molten rock material found inside Earth is called **magma**. As magma cools, atoms slow down and begin to arrange into an orderly structure. When the temperature of magma drops well below the solidification temperature of a mineral, crystals of that particular mineral may form and grow.



Reading Check How do minerals form in magma?

**Minerals from Evaporation** Minerals also form from water at Earth's surface. When water slowly evaporates, dissolved mineral material may be left behind to form crystals. You might have seen films of material left behind in a pan that once was filled with water. Minerals that were dissolved in the water are left on the surface of the pan after the water evaporates.

# **Mineral Groups**

About 3,800 minerals have been identified in nature. Some minerals are so common that they are called rock-forming minerals. Recall that few elements are needed to make up almost the

entire crust of Earth. Similarly, a few important mineral groups make up most of Earth's crust.

**Silicates** The atomic arrangement and composition of minerals allow them to be sorted into groups. Among these, the most important by volume of Earth's crust are the silicate groups.

Most minerals contain silica. Silica is a common term for a compound that contains silicon plus oxygen or silicon dioxide (SiO<sub>2</sub>). The mineral quartz is pure silica that has crystallized. In silicate minerals, the elements silicon and oxygen bond together to form a geometric structure called a tetrahedron, as shown in **Table 3.** Other metal atoms can attach to the oxygen atoms. Most silicate minerals contain silicon, oxygen, and one or more other elements.



Si-O Bond The siliconoxygen tetrahedron is the base unit for the silicates in the nonliving world. Carbon chains are fundamental units for living things. Research carbon chains and compare and contrast them with the Si-O tetrahedrons.

Table 3 Silicate Minerals				
Mineral		Photos	Silicate Structure	
Olivine			0 Si Single tetrahedron	
Pyroxene group (Augite)			Single chains	
Amphibole group (Hornblende)			Double chains	
	Biotite		မို့မို့မို့မို့ ဗေလဗေ	
Micas	Muscovite		Sheets	
Feldspars	Potassium feldspar			
reiuspars	Plagioclase			
Quartz			Three-dimensional networks	



**Activity** Make a table for at least ten minerals. Your table headings should include *Common Minerals*, *Occurrences*, and *Uses or Products*.

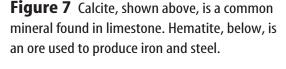
**Silicate Structures** You might have watched buildings go up in your neighborhood. All the buildings are put together using similar construction materials. What really makes them different is how these materials are put together. Silicate mineral groups are similar. Silicates all contain silicon-oxygen tetrahedrons that are linked together in different ways.

The simplest silicate structures have silicon-oxygen tetrahedrons that are not linked together. By joining silicon-oxygen tetrahedrons together, chains, sheets, and three-dimensional framework structures can form, as shown in **Table 3.** Keep in mind that each group of silicates has a different structure, but most contain the silicon-oxygen tetrahedron as a basic structural unit.

**Minerals of the Crust** Several important silicate groups form most of Earth's crust. Quartz and some feldspar group minerals, shown in **Table 3**, are relatively low in density and form at relatively low temperatures compared to other silicate minerals. Together, quartz and feldspar group silicates make up most of Earth's continental crust.

In contrast, Earth's oceanic crust is denser and contains a larger percentage of silicates whose tetrahedrons are linked together as single chains or are not linked. For example, chain silicates such as the pyroxene group, and single tetrahedron silicates of the olivine group, along with plagioclase feldspars, make up the majority of crust beneath the oceans.

Important Non-silicates Some important mineral groups are not silicates. These include the carbonates, oxides, halides, sulfides, sulfates, and native metals. The non-silicate groups are a source of many valuable ore minerals and building materials. To be an ore, a mineral must occur in large enough quantities to be economically recoverable. One example of an important ore of iron is the mineral hematite, an iron oxide. Aluminum comes in part from bauxite, a mixture of aluminum oxides. People eat salt processed from the halide mineral halite, and use calcite (a carbonate) to make cement. Common non-silicate minerals are shown in **Figure 7.** 









To which mineral group does hematite belong?

#### **Mineral Uses**

For centuries, humans have relied on minerals for their everyday needs, for example, humans have always needed salt. Civilizations have advanced themselves through the use of their mineral wealth. Think of the exploration and conflicts that took place over gold. Europeans spent vast sums of money and risked many lives to search for gold.

People use minerals either directly as objects of wealth, or as raw materials to make things. Those regions fortunate enough to have large quantities of hematite, iron ore, advanced rapidly. Think of all of the things made from iron and steel. Without iron there would be no machinery as we know it today for manufacturing goods.

Not all minerals need to provide metals to be valuable. Nonmetallic minerals are valuable as well. For example, quartz is used to make glass and glass fibers. Glass fiber is used to make fiber optical cables. Most sands and gravels are largely quartz. When mixed with cement (calcite), quartz is used to make concrete. Think of all the things that are made of concrete.



Salt Mining Because of its use as a preservative for food in ancient times. salt was a valuable resource. Salt has been collected by evaporating seawater and by mining deposits from below Earth's surface. Research the word salary in terms of its connection with salt.

#### section

#### **Summary**

#### **Common Elements**

• Few elements form the bulk of materials in Earth's crust.

#### **Mineral Properties**

- A mineral is an inorganic solid with a predictable chemical composition.
- All minerals occur in nature and have orderly internal atomic arrangements.
- Physical properties of minerals may reflect their chemical composition and orderly atomic arrangement.

#### **Mineral Formation and Mineral Groups**

- Minerals crystallize mainly from fluids and molten rock material, as atoms come together to form crystalline structures.
- Minerals can be sorted into two broad categories: silicates and non-silicates.

#### **Mineral Uses**

 Civilization depends on minerals for a wide range of uses, from direct wealth to making products.

#### **Self Check**

- 1. Determine whether diamonds produced in laboratories are considered to be minerals.
- 2. **Describe** two ways that minerals form.

review

- 3. Compare and contrast mineral cleavage and mineral fracture.
- 4. Explain why it is useful to test more than one physical property when attempting to identify a mineral.
- **5. Think Critically** What does the fact that mower blades become dull tell you about the hardness of the blades?

#### **Applying Math**

- **6. Calculate Area** Imagine you have a halite cube that measures 3 cm on each edge. What is the total surface area of the cube?
- 7. Calculate Area Imagine cleaving the halite cube in question 6 exactly in half, perpendicular to one of its faces. What is the total surface area now?
- 8. Analyzing Variables What is the relationship between particle size and surface area for a given volume of material?

# Be a Mineral





Detectives must gather facts and physical evidence to deduce the events that took place during a crime. Much like detectives, geologists gather physical evidence to better understand Earth processes. First, minerals are identified, and then their histories sometimes can be interpreted.

# Real-World Problem

How is it possible to distinguish similar-looking materials from each other?



#### Goals

- Observe and record physical properties of minerals.
- Determine mineral names using your observations and identification keys.

#### **Materials**

mineral samples penny unglazed porcelain tile nail Mohs hardness scale glass plate Reference Handbook, "Minerals"

#### Procedure

- 1. Set up a data table on your paper. Label the columns using, at least: *Mineral Number, Color, Hardness, Streak, Cleavage, Fracture, Other Observations* (like smell, feel, or heft), and *Mineral Name*.
- 2. Obtain numbered mineral specimens from your teacher. Observe each mineral and accurately record the data based on your tests for physical properties. Be descriptive and broad in your observations.

Hints: When determining hardness, test several different spots on the sample. Remember the hardness of your fingernail is a little more than 2; penny, a bit more than 3; steel nail, 5–6; glass, about 5–5.5. Minerals can have both cleavage and fracture at the same time. Cleavage is expressed as how many unique planar directions are present, and the angles formed when more than one direction occurs.

3. Using the Reference Handbook, "Minerals" at the back of your book, attempt to identify each unknown mineral. Your teacher may tell you when you are incorrect and allow you try again.

# Conclude and Apply

- Explain why certain minerals seemed to be difficult to identify.
- **2. Explain** why certain minerals seemed to be easy to identify.
- **3. Determine** which physical properties were most reliable for identification overall.
- **4. Determine** which physical properties seemed to be least reliable.

# Communicating Your Data

**Compare** your results with your classmates. Discuss what kind of mineral evidence a detective might obtain from a crime scene and how it might be used.

# **Igneous Rocks**

## **Reading Guide**

#### What You'll Learn

- Describe the types of materials present in most rocks.
- Explain how and where igneous rocks form.
- Classify igneous rocks.

# Why It's Important

Igneous rocks make up the majority of Earth's crust and mantle and contain clues about processes that form them.

#### Review Vocabulary

**mixture:** combination of two or more substances that can be physically separated

#### **New Vocabulary**

- rock
- texture
- intrusive igneous rock
- extrusive igneous rock

#### What's a rock?

A **rock** is a naturally formed mixture containing minerals, rock fragments, or volcanic glass bound together. Most rocks contain crystals of minerals that may or may not be wellformed. Rocks are identified by their composition and texture.

The **texture** of a rock describes the size, shape, and arrangement of the rock's components. The rock-making process is a continuous cycle. Part of this cycle involves rock formed from magma inside Earth.



What types of materials compose rocks?

# **Intrusive Igneous Rocks**

Igneous rocks are those that form from molten magma. Geologists have termed igneous rocks that formed inside Earth plutonic, after Pluto, the Greek god of the underworld. Such rocks also are called **intrusive igneous** rocks because they form within, or push into, regions of Earth's crust, as shown in **Figure 8**.

**Figure 8** These light-colored veins of intrusive igneous rock formed when molten rock material cut through surrounding rock layers.



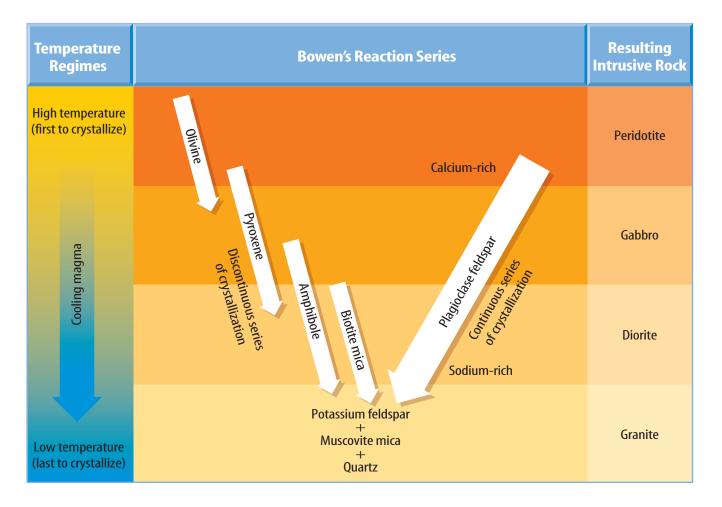
**Nature of Magma** As it passes through rock, magma might cause partial melting of the rock it pushes into. Minerals have different melting temperatures. As a result, the hot magma can cause some of the minerals in the surrounding rock to melt. This interaction between magma and the rock it pushes into can cause changes in the rock, changes in the magma, or both.

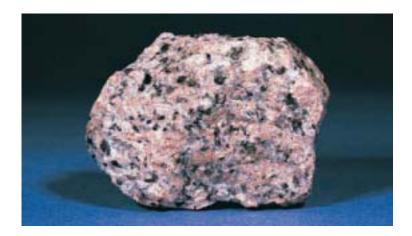
You're familiar with the freezing of liquid water to form ice at 0°C. Minerals freeze at very high temperatures, ranging from several hundred degrees Celsius to more than 1,000°C. Magmas generally must be cooled below the freezing temperature of a mineral in order for it to begin crystallizing.

**Intrusive Igneous Rock Composition** As magma cools, different minerals crystallize at different temperatures. When the temperature of the magma is high, olivine, pyroxene group minerals, and plagioclase feldspars crystallize first. These minerals are dense and tend to settle toward the bottom of the magma chamber. Late-forming, less dense minerals tend to solidify at lower temperatures and float to the top of the magma chamber. These relationships are shown in **Figure 9.** 

**Figure 9** The Bowen's reaction series, shown below, illustrates the sequence in which minerals crystallize from magma at different temperatures.

**Identify** two pairs of minerals that are likely to be found in the same rock.





**Figure 10** This piece of coarse-grained granite contains mineral crystals, such as black crystals of the mineral hornblende, that are large enough to be seen without magnification.

Where Intrusive Igneous Rocks Form The composition of intrusive igneous rocks depends on where they form. Igneous rocks with abundant quartz generally form in continental crust. Those with little or no quartz generally form deep in continental crust or in oceanic crust. The minerals in the rock depend on the chemical composition of the magma from which it formed.



Where might you find igneous rocks with little or no auartz?

**Composition of Igneous Rocks** Igneous rocks form from three types of magma—granitic magma, basaltic magma, or andesitic magma. As a result, igneous rocks are classified into three groups—granitic rocks, basaltic rocks, and andesitic rocks. Granitic rocks include rocks, such as granite, that contain the minerals quartz, potassium feldspar, mica, and hornblende. Rocks in the granitic group have low densities and are abundant in continental crust. Basaltic rocks contain the minerals plagioclase feldspar, pyroxene, and olivine. These rocks are denser than those in the granitic group and form much of the oceanic crust. Finally, andesitic rocks have compositions intermediate between granitic and basaltic rocks.

**Intrusive Igneous Rock Textures** Recall that texture describes the size and arrangement of rock components. The size of the mineral crystals in a rock is called the grain size. Large grains are crystals that are big enough to see with the unaided eye. Rocks with large grains, like the rock shown in Figure 10, are called coarse-grained. Grain size depends on how quickly the magma cooled that formed the rocks. If the magma cools quickly, crystals have less time to grow and grain sizes are small. If the magma cools slowly, crystals have more time to grow and become large.

## **Extrusive Igneous Rocks**

Intrusive igneous rocks form when magma enters, or intrudes, into cracks in Earth's crust and cools. Some cracks in the crust reach Earth's surface. Then magma can flow through these cracks onto the surface. Recall that magma that reaches Earth's surface is called lava. When lava is erupted, or extruded, onto the surface, rocks form as the lava cools, as shown in **Figure 11.** Extrusive igneous rocks are rocks that form from lava erupted at Earth's surface.

Rates of Cooling If a volcanic eruption is on land, lava pours out into the air. If a volcanic eruption is on the ocean floor, lava flows into water. In either case, the temperature of the lava is much hotter than the temperature of the surrounding air or water. Because the temperature difference between the lava and its surroundings is large, the lava cools quickly.

When magma cools inside Earth's crust and forms intrusive igneous rocks, the crustal rock surrounding the magma can be hot. Then the temperature difference between the magma and its surroundings is not as large as when lava erupts on the surface. As a result, magma that intrudes into the crust cools more slowly than magma that extrudes onto the surface.

**Figure 11** Lava erupts from the Kilauea volcano on the island of Hawaii. The cracks in Earth's crust through which magma flows to the surface at Kilauea may extend to 60 km in depth.



**Extrusive Igneous Rock Textures** Extrusive igneous rocks have different textures than intrusive igneous rocks. Because lava cools quickly, crystals that form do not have much time to grow. As a result, extrusive igneous rocks have small grain sizes. Rocks with small grain sizes are called fine-grained. Fine-grained, extrusive igneous rocks often have grain sizes that are too small to be seen without magnification. Sometimes lava cools so quickly that almost no crystals are formed. Then the rock that forms has a glassy structure. Obsidian is an example.

#### **Applying Math**

#### **Use Percentages**

**EXTRUSIVE IGNEOUS ROCK CLASSIFICATION** The amount of silica (SiO<sub>2</sub>) in an extrusive rock formed when magma cools is used as a classification system. Basaltic rock contains 45 percent to 55 percent SiO<sub>2</sub>, andesitic rock contains 55 percent to 65 percent SiO<sub>2</sub>, and rhyolitic rock contains 65 percent to 75 percent SiO<sub>2</sub>. A 151-g rock is found to contain 89 g of SiO<sub>2</sub>. Based on the percentage of SiO<sub>2</sub> in this rock, how would you classify it?

#### **IDENTIFY** known values and the unknown value

Identify the known values:

151-g rock means 
$$m_{rock} = 151 \text{ g}$$
  
89 g of SiO<sub>2</sub> means  $m_{silica} = 89 \text{ g}$ 

Identify the unknown value:

percentage of 
$$SiO_2$$
 means percent  $SiO_2 = ? \%$ 

#### SOLVE the problem

Divide the mass of SiO<sub>2</sub> by the total mass of the rock and multiply by 100%:

percent 
$$SiO_2 = \frac{m_{silica}}{m_{rock}} \times 100\% = \frac{89 \text{ g}}{151 \text{ g}} \times 100\% = 59\%$$

The rock should be classified as andesitic.

#### **CHECK** your answer

Does your answer seem reasonable? Check your answer by multiplying the percentage you calculated (expressed as a decimal) by the mass of the rock. The answer should be the mass of silica given in the problem.

#### **Practice Problems**

- 1. What is the greatest mass of SiO<sub>2</sub> that could be found in a 212-g rhyolitic rock?
- **2.** A 120-kg basaltic boulder found in Hawaii contains 47 percent SiO<sub>2</sub>. How many kilograms of SiO<sub>2</sub> are in the boulder?

For more practice problems, go to page 879 and visit Math Practice at gpescience.com.



#### Topic: Igneous Rock Textures

Visit **gpescience.com** for Web links to information about igneous rock textures.

**Activity** Select gabbro and granite from plutonic microtextures. Make a detailed, colored sketch of each of the photomicrographs of these rocks. Label your drawings. Repeat the activity by selecting nepheline basalt and rhyolite from the volcanic microtextures file.

**Extrusive Igneous Rock Composition** The difference between extrusive igneous rocks and intrusive igneous rocks is due mainly to the difference in their textures. Extrusive igneous rocks are fine-grained with small crystals. Intrusive igneous rocks are coarse-grained with large crystals. However, extrusive igneous rocks are formed from the same three types of magma as intrusive igneous rocks.

For example, granitic magma forms coarse-grained granite when it cools slowly inside Earth's crust. The same magma forms a fine-grained rock called rhyolite when it cools quickly at Earth's surface. This means that the intrusive igneous rock granite and the extrusive igneous rock rhyolite have similar chemical compositions. In **Figure 12**, it is the differences in crystal sizes that cause the granite and rhyolite to look different. Similarly, basaltic magma that forms coarse-grained gabbro when it cools slowly forms fine-grained basalt when it cools rapidly. These rocks are also shown in **Figure 12**.



What is the difference between granite and rhyolite?

**Figure 12** Different rocks form from granitic or basaltic magmas, depending on how quickly the magma cools. Coarse-grained granite and fine-grained rhyolite both form from granitic magmas. Coarse-grained gabbro and fine-grained basalt both form from basaltic magmas.

**Compare and contrast** the intrusive and extrusive rocks shown here.

	Granitic	Basaltic
Intrusive	Granite	Gabbro
Extrusive	Rhyolite	Basalt

**Gases in Magma** When lava erupts at Earth's surface, other types of extrusive igneous rocks can be formed. Magma contains small amounts of dissolved gases, such as water vapor and carbon dioxide. As magma rises up closer to the surface, the pressure exerted on the magma by the surrounding rock decreases. When the pressure becomes low enough, the gases begin to escape from the magma. The escaping gases form bubbles in the magma. When the lava cools at the surface, the bubbles can be trapped. The rock that forms looks spongy and is filled with holes. Pumice, shown at the bottom of **Figure 13**, is an extrusive igneous rock formed in this way.

In some cases, escaping gases can cause lava to erupt explosively. When an explosive eruption occurs, lava is ejected into the air. Large blobs of lava solidify as they move through the air, forming teardrop-shaped rocks called volcanic bombs. An example of a volcanic bomb is shown in **Figure 13**.





**Figure 13 Top** Volcanic bombs are formed as lava moving through the air solidifies. **Bottom** Pumice forms from lava containing bubbles.

# section

#### Summary

#### What's a rock?

- Rocks are mixtures of various natural materials.
- The composition and texture of a rock indicate how it formed.

#### **Intrusive Igneous Rocks**

- There are three types of magma composition—granitic, basaltic, and andesitic.
- Intrusive igneous rocks are coarse-grained rocks that form from magma that cools slowly within Earth's crust.

#### **Extrusive Igneous Rocks**

- Extrusive igneous rocks are fine-grained rocks that form from magma that cools rapidly at Earth's surface.
- Extrusive and intrusive igneous rocks formed from the same type of magma have similar compositions but different textures.
- Dissolved gases in magma can cause explosive volcanic eruptions.

#### **Self Check**

1. List the materials that can form a rock.

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- **2. Compare** the magma that forms the continental crust with the magma that forms the oceanic crust.
- **3. Discuss** what happens to the dissolved gases in magma as the magma ascends toward the surface of Earth.
- **4. Explain** why you would not expect to observe an igneous rock with quartz and olivine in it.
- 5. Think Critically Lava flows that are relatively low in SiO<sub>2</sub> tend to have low viscosities, or flow easily. Name an igneous rock that you would expect to form from a low-viscosity lava flow. Explain your answer.

#### **Applying Math**

6. Calculate Granite Volume Granite occurs in very large masses called batholiths. The Sierra Nevada batholith in California is a batholith made up of many separate intrusions. Suppose the mountain range averaged 8.33 km in thickness, extended 700 km north to south, and averaged 91.66 km wide. Approximately how many cubic kilometers of granite are in that mountain range?

# **Sedimentary Rocks**

## **Reading Guide**

#### What You'll Learn

- Explain how and where sedimentary rocks form.
- Discuss how sedimentary rocks are used to interpret Earth's history.
- Describe how sedimentary rocks are classified.

# Why It's Important

Knowledge of sedimentary rocks helps you understand where resources such as fossil fuels and groundwater come from.

#### Review Vocabulary

**precipitate:** an insoluble compound that comes out of solution during a chemical reaction

#### **New Vocabulary**

- clast
- pore space
- cementation

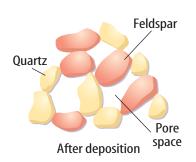
**Figure 14** Rocks that are tumbled more than 3,000 km along the bottom of the Colorado River, shown below, can be broken into fine particles before they reach the Gulf of California.

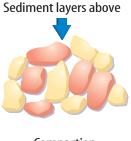
#### **Rocks from Surface Materials**

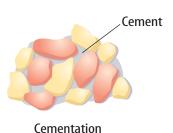
Recall that rock is a mixture of minerals. Some of these minerals could be in bits and pieces of other rocks. Such small bits and pieces are called **clasts**. The word *clast* is from the Greek *klastos* which means "broken."



**Surface Attack** What could reduce rocks of the crust to smaller sizes? Inside Earth, rock is at high temperatures and is under high pressure. However, the high temperatures and pressures do not cause the rock to break up. In contrast, rock exposed at the surface is attacked by the weather. This action over a long time breaks rocks down into smaller-sized pieces and loosens them from their original positions. Loose chunks of rock, in turn, are attacked more easily by water and air, and are able to smash into each other. It is this slow, but constant smashing, grinding, and dissolving of clasts that can take place in rivers and streams, as shown in Figure 14, and in other environments.







Compaction

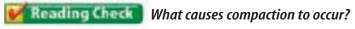
**Figure 15** Sandstone can form when sand grains are deposited, compacted, and cemented together.

**Transportation and Deposition** Mechanical weathering occurs when physical forces break rocks into smaller clasts. For example, collisions between rocks cause mechanical weathering. Gravity, wind, flowing water, and moving ice can carry clasts to new locations. As clasts are transported they grind against each other and other hard objects in their environment. This grinding can cause clasts to become rounded.

Clasts can pile up when they are deposited after being transported. When clasts pile up, there are spaces between the individual clasts, as shown in **Figure 15.** The empty space between clasts is called **pore space**. All irregularly shaped and rounded objects have some pore space when they are piled up. Some clasts are in the form of flat plates and can fit together with only a small amount of pore space. Water, oil, and natural gas found beneath Earth's surface are stored in the pore spaces of sedimentary rocks.

**Compaction** Eventually, clasts can form sedimentary rocks. After clasts are formed, transportation and deposition can cause clasts to be buried in low areas. As more material is deposited in an area, clasts become buried deeper. The pressure on the bottom layers continues to increase, due to the increasing weight of the material above these layers. This pressure causes clasts to be forced together, as shown in **Figure 15**, reducing the pore space and causing the clasts to stick together.

The process by which clasts stick together by being pushed together is called compaction. In contrast to the formation of clasts, which occurs at Earth's surface, compaction occurs beneath Earth's surface.



**Cementation** Water moving between clasts carries dissolved minerals that can act as cement. Common minerals that cement clasts together include quartz, calcite, hematite, and clay minerals. Under certain conditions these minerals slowly precipitate out of water and fill spaces between clasts. This process is called cementation. Figure 15 shows how compaction and cementation form sedimentary rock.

# **Detrital Sedimentary Rocks**

Detritus, from the Latin deterere, which means "to lessen or wear away," is another name given to clasts. Sedimentary rocks that are made mostly of clasts are called detrital sedimentary rocks. Clasts have different sizes and geologists classify clasts according to their size. In order of decreasing size, clasts are classified as gravel, sand, silt, or clay, as shown in **Figure 16.** To geologists, these categories describe only the size of clasts, and not their composition.

**Sorting of Clasts** The size of a clast determines how the clast can be transported. It takes more force to move large clasts than it takes to move small ones. For example, wind and slow-moving water can only move small particles. However, fast-moving water can pick up and move large clasts, as well as small ones. As a result, wind and slow-moving water separate clasts according to size by transporting the small clasts and leaving the larger clasts behind. The separation of clasts according to size by wind or water is called sorting. If you sampled the particles in a muddy river, gravel and sand might be on the bottom of the river. These clasts would be too heavy to be carried along by the river. However, the river water would contain silt or mud particles that were small enough to be transported by the water.

Sorting can also occur as clasts are deposited. Deposition of clasts occurs when the clasts are no longer being transported. For example, a fast-moving river can carry clasts of different sizes. As the flow of the water slows, the largest particles, gravel,

Detrital Sedimentary Rocks			
Texture (grain size)		Sediment Name	Rock Name
Coarse (over 2mm)		Gravel (Rounded fragments) Gravel (Angular fragments)	Conglomerate Breccia
Medium (1/16 to 2 mm)		Sand	Sandstone
Fine (1/16 to 1/256 mm)		Silt	Siltstone
Very fine (less than 1/256 mm)		Mud or clay	Shale

begin to settle out and are deposited first. As the flow continues to slow, sand settles out and then silt, and finally mud. This means that the river was moving faster where the gravel was deposited and slower where the silt and mud was deposited. The different-sized clasts are deposited in different areas.

**Figure 16** Sand is defined by size, not by composition. Sand doesn't even have to be made from rock material; it can be made from shells.

**Detrital Sedimentary Rock Compositions** Detrital sedimentary rock composition depends on sources of rock material that were eroded, transported, and eventually deposited. Original rock material can be dislodged and carried by streams or water currents, blown by the wind, or rafted along by moving ice. The clasts can come from all the regions that these carriers moved over or through. The number of possible combinations of different kinds of clasts is large. However, the size of clasts is controlled by the ability of the carrier to move them.

Some minerals tend to be more common in detrital sediments because they are harder or more resistant to being dissolved. Quartz is such a mineral, which is why you might have thought clasts are always made of quartz. Geologists examine sedimentary rock compositions and try to reconstruct what happened to form them. You can try to reconstruct a sedimentary rock's history by imagining all the places that clasts could have come from and how they got there.



What factors control the composition of a detrital sedimentary rock?

**Detrital Rock Classification** Just as igneous rocks are classified according to composition and texture, similar observations are used to classify detrital sedimentary rocks. Mineral composition is extremely variable, so adjectives are used to modify the general name of the rock. The general rock name is determined by clast size. The names of detrital sedimentary rocks are given in Table 4.

Clast size also provides clues to help determine the depositional environment of the sediment that formed the detrital rock. Suppose you have a sample of siltstone that contains shells of marine animals. You might conclude that the sediments were

deposited in a shallow, calm area along the coast. The calm water allows small particles like silt to settle out. The shells give you a clue that the environment was near the ocean. Perhaps the sample also has fossils in the form of marine worm tubes. The fossils are traces of organisms that might have lived in soft mud.

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Cementation Though sedimentary rocks may form in arid, desert conditions or from compaction by glaciers, most sedimentary rocks are formed from being deposited in water. Dissolved minerals in the water may precipitate onto the surfaces of the clastic particles and become the cement to hold grains of sand, silt and clay together. The minerals may also precipitate to form layered rock crystals as well. Make a supersaturated solution and allow the liquid to evaporate. Do the crystals form in layers?

Table 4 Common Clast Sizes Used to Name Sedimentary Rocks		
Common Clast Size	Rock Name	
Gravel or larger	Conglomerate	
Sand	Sandstone	
Silt	Siltstone	
Clay	Shale	



#### **Modeling Evaporites**

#### Procedure

- 1. Add to a sauce pan 1 L of tap water and 34 g (about 6 level teaspoons) of salt and stir with a spoon.
- 2. Place a lid on the pan and heat it on a hotplate to boiling. Droplets of a solution should be forming underneath the lid. This solution will be hot. Use thermal mitts to carefully remove the lid and drain off the liquid from the lid into a saucer. Replace the lid.
- Repeat step 2 several times until you have several teaspoons worth of liquid from the lid.
- 4. Carefully pour enough of the pan's contents to halffill a second saucer. Label each saucer to identify which water came from the lid and which came from the pan.
- **5.** Allow both saucers to sit undisturbed until all of the water evaporates from each.

#### **Analysis**

- 1. What do you observe in the saucers after all of the water has evaporated?
- Compare and contrast any substance you observe with some salt grains directly from the salt container. Use a magnifying lens to observe the substance in each saucer.

# **Chemical Sedimentary Rocks**

Chemical sedimentary rocks form from minerals dissolved in water. Minerals dissolved in water in lakes and other bodies of water sometimes come out of solution and form crystals. If the crystals get buried, they are forced together by compaction and stick together, forming chemical sedimentary rocks.

For crystals to form out of the solution, the solution must be saturated. A solution is saturated when the maximum amount of a material is dissolved in water. If more of the material is added, it does not dissolve. For a chemical sedimentary rock to form, first the solution containing the dissolved mineral must become saturated. This can occur in two ways. One way is to add more mineral to the solution until it becomes saturated. Then the mineral precipitates out of the solution, forming crystals.

The other way to form a saturated solution is to reduce the amount of water by letting the water evaporate. As the water evaporates, the solution becomes more concentrated. As water continues to evaporate, the solution finally becomes saturated, and mineral crystals precipitate out of the solution. Chemical sedimentary rocks formed in this way are called evaporites because evaporation of water starts their formation.

# **Biochemical Sedimentary Rocks**

If sedimentary rocks contain the remains of living organisms they are called biochemical sedimentary rocks. Most of Earth's limestone is composed, at least partially, of the remains of marine organisms that had hard parts made of calcium carbonate. The shells of the organisms were cemented together by calcite. Coquina is a variety of limestone that is formed mostly from broken shell fragments. The shells accumulated on the seafloor and were later cemented together with calcium carbonate. Most organisms whose shells contributed to the limestone-making process lived in warm, shallow seas. Animals without shells rarely contributed enough debris to make rock. More often, their soft remains deteriorated or were scavenged before they became part of a sedimentary rock.



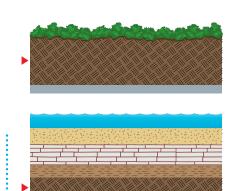
What chemical compound is limestone made of and where does it come from?

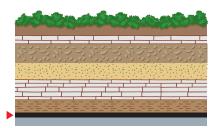
Another common rock that originates from the remains of organisms is coal. The starting material for coal is mostly plant matter. Coal is sedimentary rock composed almost entirely of the carbon that remains after plant material is compressed underground.

**Figure 17** As sediment accumulates above a layer of peat, shown at the upper triangle, the peat becomes more compressed. Continual compression drives out water and other compounds, leaving behind a form of carbon called coal, shown at the lower triangle.

**Formation of Coal** Coal usually develops from peat, a brown, lightweight deposit of moss and other plant matter. Peat forms shallow swamps or bogs in a temperate or tropical climate. Partial decay of the plant matter uses up oxygen in the swamp water. This stops further decay and the remaining organic matter is preserved. Peat is transformed into coal largely by compaction after it has been buried by more sediment layers.

Look at **Figure 17.** Coal goes through a series of changes as it forms from peat. Each stage of compaction drives out more impurities and leaves behind a more concentrated form of carbon. Coal often lies within repeated sequences of sandstone, shale, and limestone, which indicate alternating continental and marine conditions. This implies a low-lying environment near the sea, such as lagoons, large deltas, and swampy coastal plains. By studying coal fields, changes in Earth's climate, geological activity, and life forms may be traced and compared.





#### section

#### review

#### **Summary**

#### **Rocks from Surface Materials**

 Sedimentary rocks have three main types that reflect their origins: Detrital, chemical, and biochemical.

#### **Detrital Sedimentary Rocks**

- Detrital sedimentary rocks can be composed of a wide variety of clasts.
- Clasts vary widely in size.
- Many possible combinations of clast composition and clast size produce a large number of detrital sedimentary rocks.

#### **Chemical Sedimentary Rocks**

 Chemical sedimentary rocks form as minerals precipitate from water rich in dissolved mineral matter.

#### **Biochemical Sedimentary Rocks**

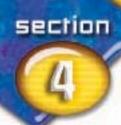
 Biochemical sedimentary rocks form from the remains of organisms.

#### **Self Check**

- 1. Describe the requirements for a material to be classified as a sedimentary rock.
- 2. Compare and contrast the formation of an evaporite rock to one of detrital origin.
- 3. Explain how clast size affects transportation of different-sized clasts. Also, explain the order in which different-sized clasts are deposited.
- 4. Think Critically Suppose a stream floods over its banks. If you dug a hole through the layers of sediment deposited near the edge of the channel after the water receded, what would you likely see?

#### **Applying Math**

5. Calculating Sedimentation Rate Imagine that thin layers of sediment are being added to a lake that is 10 m deep. Suppose the average yearly influx of sediment is 2.5 mm. About how long would it take to fill in the lake with sediment?



# Metamorphic Rocks and the Rock Cycle

# **Reading Guide**

#### What You'll Learn

- Identify physical conditions that cause metamorphism.
- Explain where metamorphism occurs.
- Classify metamorphic rocks.

## Why It's Important

An awareness of change leads to an improved ability to adapt to change.

#### Review Vocabulary

**chemical reaction:** process in which one or more substances are changed into new substances

#### **New Vocabulary**

- foliated
- rock cycle

# Metamorphic Rocks In the last section you learned

In the last section you learned that sedimentary rocks show great variety with many different combinations of composition and texture. The same is true for metamorphic rocks. Metamorphic rocks, like the ones shown in **Figure 18**, are rocks that have been changed by some combination of thermal energy, pressure, and chemical activity. As these agents begin to

act on a rock, its atoms rearrange and sometimes form new minerals. The word metamorphic comes from two stems, "meta" (to change) and "morph" (form). Any igneous, sedimentary, or metamorphic rock can be changed through metamorphism.

Metamorphic rocks form under conditions that are between the conditions that form igneous and sedimentary rocks. Sedimentary rock formation occurs at lower temperatures and pressures than metamorphic rock formation. However, the formation of igneous rocks requires temperatures high enough to melt rocks. Igneous rock formation occurs at higher temperatures than metamorphic rock formation, which occurs while rocks remain solid.

**Figure 18** Sharp folds sometimes display intense transformations in metamorphic rocks.



#### **Metamorphic Rock Composition**

Metamorphic changes in rocks are caused by thermal energy, pressure, and chemical reactions. The presence of water within the rock enables these chemical reactions to occur. Some rocks contain water molecules as part of their chemical composition. Sometimes hot water can flow into the rock and cause chemical reactions.

Reading Check What are three causal agents of metamorphism?

**Changing Minerals** Clay minerals, micas, and amphiboles are examples of minerals that contain water in their crystal structures. Clay minerals tend to form micas when metamorphic changes occur. If the pressure and temperature within the rock continue to increase, the water can be driven away completely. Minerals, such as garnet, that contain some of the same elements found in clays (aluminum and silicon) can result. In this way, some new minerals form by dehydration at higher temperature and pressure.

Regional and Contact Metamorphism What causes the pressure on a rock and its temperature to change? Regional movements of Earth's tectonic plates can cause rocks to be buried deeply, producing large increases in the temperature of the rocks. Also, enormous forces are exerted on rocks when plates move, producing large increases in pressure. Metamorphic changes in rocks that occur over large areas are called regional metamorphism. Metamorphic changes can also occur over smaller regions. For example, when magma intrudes into rock, metamorphic changes can occur in

rock that is in contact with the magma. These metamorphic changes are called contact metamorphism.

# **Metamorphic Rock Textures**

Metamorphic processes produce rocks with different textures. Recall that *texture* describes the size and orientation of the crystals in a rock. Some metamorphic rocks have foliated textures, as shown in **Figure 19.** Textures that are **foliated** have crystals arranged in layers and bands. Foliated textures are formed under high pressure. Metamorphic textures can also be nonfoliated, like the rock shown at the bottom of Figure 19, where crystals are in more random orientations.

Figure 19 Folio means "leaf." Foliated texture has the appearance of layered leaves or pages of a book. The texture of the first metamorphic rock shown below is foliated; the second is nonfoliated.



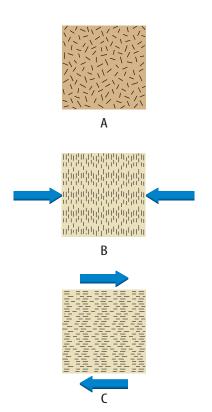


Figure 20 Direction of applied force affects orientation of mineral grains.

- A Mineral grains are randomly oriented when no directed force is involved.
- **B** Orientation of mineral grains is perpendicular to the direction of pressure caused by compression.
- Mineral grains are parallel to the direction of shearing force.



# **Topic: Metamorphic Rock**

Visit gpescience.com for Web links to information about metamorphic rock textures.

**Activity:** Select from metamorphic microtextures: Gneiss, marble, and foliation. Make a detailed colored sketch of each of the photomicrographs showing these textures. Label your drawings.

Foliated Rocks The most common sedimentary rocks in Earth's crust are rocks, such as shale and siltstone, that are formed from mud. When metamorphosis occurs, the clay minerals in these rocks change to minerals in the mica group, such as muscovite. As metamorphosis continues to occur, the grain size of the mica group minerals tends to increase.

When squeezed and heated, layers of mica line up in a direction that is perpendicular to the direction of compression or parallel to the direction of shearing, as shown in Figure 20. For example, slate is a fine-grained, foliated metamorphic rock that splits easily along flat, parallel planes. It typically formed when shale was compressed, causing mica grains to orient perpendicular to the compression.



How does compression affect the orientation of mica grains in metamorphic rocks?

Sometimes it's easiest to consider foliated rocks as a progression of increasing metamorphic conditions. The smallest-grain sizes in foliated textures occur in slate, which forms thin layers and exhibits rock cleavage. The rock cleavage comes from the parallel alignment of mineral grains within the rock. If the metamorphic conditions increase, some of the mineral grains in the slate grow and produce the rock phyllite. With continued grain growth, a shiny mass of mica sheets called schist (SHIHST) forms. Finally, at the highest level of change a rock called gneiss (NISE) is produced. Gneiss rock textures often are banded, and gneisses generally represent the limit between metamorphic and igneous conditions.

**Nonfoliated Rocks** Similar in texture to intrusive igneous rocks, nonfoliated metamorphic rocks tend to have random crystal orientation and uniform grain size. In general, mineral grains tend to grow as the amount of metamorphism increases. Imagine a limestone with microscopic grains. Under the influence of temperature, pressure, and in the presence of fluids, this rock recrystallizes in large grains of calcite. This resulting rock is marble, and it has essentially the same chemical composition as the original limestone.

**Shock Metamorphism** Regional and contact metamorphism cause changes that can occur over millions of years. However, shock metamorphism can produce metamorphic changes in seconds. Shock metamorphism is caused when a meteorite strikes Earth's surface, generating high temperatures and pressures at the impact site. An example of an meteorite impact that caused shock metamorphism is shown in Figure 21.

#### **NATIONAL** GEOGRAPHIC VISUALIZING SHOCK METAMORPHIC ROCK

#### Figure 21

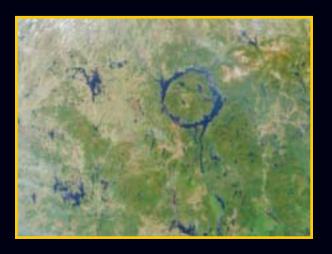
arth materials undergo change, even when buried far below the surface. Deep in the crust, high temperature and pressure conditions alter the chemical composition and structure of rocks in predictable ways over time, producing metamorphic rocks. Metamorphism, however, also can occur rapidly, violently, and without warning.

Scientists estimate that the force created by a meteorite impact could be nine million times greater than atmospheric pressure. This type of collision would send enormous shock waves throughout surrounding rock strata, rearranging atoms into new crystal structures stable at higher temperature, and pressure conditions.





Large meteorite impacts leave scars that can remain visible for millions of years. Taken from the space shuttle, this image shows the *International Space* Station above the Manicouagan impact crater in Quebec, Canada. The meteorite that created this crater struck Earth 214 million years ago, hurling debris high into the atmosphere and leaving evidence in the rock record worldwide.



With a diameter of 100 km, the Manicouagan crater is one of the largest impact structures preserved on Earth. The force of the collision caused rock melting and rock metamorphism to a depth of about 9 km. Mineral grains in metamorphic rocks at the site are deformed extensively, evidence that an intense compression wave shocked the strata.

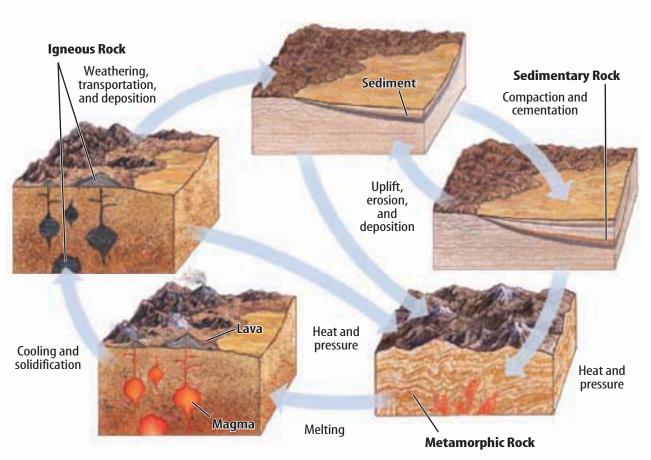
# **Classifying Metamorphic Rocks**

Metamorphic rocks can be classified by their texture. Metamorphic rocks can be foliated or nonfoliated. If they are foliated, they can be classified as slate-like, schistlike or gneiss-like. Metamorphic rocks can also be classified according to their mineral composition. For example, a nonfoliated quartz-rich metamorphic rock is a quartzite. Marble is a nonfoliated metamorphic rock made of calcite. A rock with a schistlike texture made of garnet and mica is a garnet-mica schist.

# The Rock Cycle

Rocks above and below Earth's surface are continually being changed into other types of rocks. For example, high temperatures and pressure can change igneous and sedimentary rocks into metamorphic rocks. Sedimentary and metamorphic rocks can be melted to form igneous rocks. Weathering, compaction and cementation can change igneous and metamorphic rocks into sedimentary rocks. A rock can even be changed into a different rock of the same type. The continual changing of rocks into different types is called the rock cycle, which is summarized in Figure 22.

**Figure 22** The rock cycle is a continual process in which rocks change from one type to another.



**Conservation of Matter in the Rock Cycle** As rocks move through the various stages of the rock cycle, matter is always conserved. This means that matter is not created or destroyed. For example, minerals from granite are found in the clasts formed by the weathering of those igneous rocks. These same minerals could be part of the sedimentary rocks formed from these clasts. When minerals in rocks are dissolved in water, the atoms are not destroyed, but are spread throughout the solution. These atoms then become part of the minerals that precipitate out of the solution when chemical sedimentary rocks form. The atoms in any rock are never destroyed, but can be rearranged to form new materials.

The arrows in **Figure 22** show the different ways rocks can be converted from one type to another. Some rocks in Earth's crust might not have passed through each stage of the rock cycle. Other rocks on Earth might have passed through the different stages of the rock cycle many times.



Describe several examples of how matter is conserved in the rock cycle.

# section



#### review

#### **Summary**

#### **Metamorphic Rocks**

 Metamorphic rocks can form from any preexisting rocks.

#### **Metamorphic Rock Composition**

 Agents of metamorphism can cause new textures and new minerals to form.

#### **Metamorphic Rock Textures**

- Metamorphic rocks are foliated or non-foliated.
- As metamorphic conditions increase in magnitude, mineral grains may grow larger.

#### **Metamorphic Rock Classification**

- Metamorphic rocks are classified based on mineral composition and texture.
- As with all rock classifications, some metamorphic rocks are exceptional and not easily categorized.

#### The Rock Cycle

 Although rocks are subject to many changes, matter is conserved through processes of the rock cycle.

#### **Self Check**

- 1. Explain the requirements for a material to be called a metamorphic rock.
- 2. Compare and contrast foliated and non-foliated textures.
- 3. List the following sedimentary rocks: limestone and shale. Provide the respective common names of the metamorphic rocks that each one becomes.
- **4. Identify** which rock in guestion 3 is foliated.
- **5. Critical Thinking** A marble contains occasional layers of the mineral muscovite. What possible parent rock composition could have been metamorphosed to produce this rock?

#### **Applying Math**

**6. Calculate Mass** Suppose a sculptor wants to use marble with an average density of about 2.7 g/cm<sup>3</sup>. The block of marble is one meter on every side. What is the mass of the block? If the sculptor knows from experience that the finished product will only use 45% of the block, and the rest is waste, then what will the mass of the statue be?



#### Goals

- **Observe** physical properties of minerals in rocks to determine their compositions.
- Classify each rock according to general type: Igneous, sedimentary, or metamorphic.
- **Identify** each rock based on its composition and texture.

#### **Materials**

rock samples nail penny (pre-1986) magnifying lens or particle size chart dilute HCl paper towels glass plate \* binocular microscope unglazed porcelain tile

"Rocks" \*Alternate material

#### **Safety Precautions**

Resource Handbook,



# Identifying Rocks

#### Real-World Problem

You've learned to identify most everything around you. This is an automatic process most of the time. You learned by repetition and by asking what things are called. By the time you were five years old you could name many different kinds of objects. You could identify the people in your life. You might not have had the same experience in identifying rocks—at least not yet. In this lab, you will identify rocks using a more formal approach. How can you determine the composition and texture of common rocks? What can a rock's composition and texture indicate to you about how it was formed?

#### **Procedure**

- 1. Construct a horizontal data table with ten columns and four rows.
- 2. Label the tops of columns 1 through 10, in the top row, as follows:
  - 1) Sample number
  - 2) General rock type (igneous, sedimentary, metamorphic)
  - 3) Crystals (yes/no)
  - 4) Grain size (large/small/none)
  - 5) Gas-bubble holes (yes/no)
  - 6) Fossils (yes/no)
  - 7) Particle size (gravel/sand/silt/clay)
  - 8) Foliations (yes/no)
  - 9) Additional observations



# Using Scientific Methods

- **3.** Obtain three rocks provided by your teacher.
- 4. **Observe** each rock. First, try to determine if it is igneous, sedimentary, or metamorphic. Then record everything else you observe. Your data table columns will serve as a checklist to help organize your observations.

**WARNING:** If you choose to use the acid test for calcite identification, use only one drop of HCl. A positive reaction to acid is the presence of tiny bubbles rising through the drop. Blot



the liquid off the sample with a paper towel before leaving it. Be careful to keep acid away from skin and clothing.

- **5. Identify** the rock with the help of Resource Handbook, "Rocks," at the back of your textbook.
- **6. Repeat** steps 4 and 5 to check that your results are replicated. Keep an open mind.

# 🧶 Analyze Your Data-

- **1. Identify** the texture observations that helped you distinguish igneous rocks from sedimentary rocks.
- **2. Determine** which rock samples required the fewest tests to identify them and explain why.

# Conclude and Apply

- **1. Evaluate** rocks according to difficulty for identifying and classifying.
- **2. Explain** which observations were useful for the largest number of rock samples.
- **3. Evaluate** your data table in terms of including important observations. Explain whether there were any observations you left out of your data table that are critical for distinguishing rocks.



**Present** your findings to the class. Discuss any observations that were different from those of your classmates. Discuss the column headings you included in your data table and defend your choices.

# TIME

# SCIENCE AND SOCIETY

SCIENCE ISSUES THAT AFFECT YOU!

# Earth Materials at Work



Kaolinite, a type of clay, is a common mineral on Earth.

## What is clay, and where does it come from?

hat do a commode, a brick, and a coffee mug have in common? While these items have widely different uses, they share an important component—a material called clay. Clay is found in many locations worldwide. Because of its unique properties and availability, clay has been used by civilizations throughout history to make items including building materials, pottery, and tablets for recording information.

Clay forms through weathering, crystallization, and deposition of Earth materials. The

word *clay* really represents an entire group of many different minerals. These minerals have particles with a diameter of 0.004 mm or less. When wet, most

clay minerals can be molded into a variety of shapes. When water is driven off under high temperature conditions, the material may become as hard as stone.

Clay deposits typically are found in sedimentary rock layers close to Earth's surface. As a result, clay mines are generally shallow, with depths of less than 150 m. Companies in the United States often reclaim the landscape that they mine. First, the topsoil and uppermost clay layer are removed and stored at another location. After clay is mined from an area, leftover Earth materials are returned to the pit. This layer is covered with topsoil, into which vegetation is planted.

Ceramic materials have diverse applications in manufacturing, building, art, and everyday life. Products made from clay minerals include floor tiles, fine china, and dental porcelain. The import, export, and use of clay materials contribute significantly to the world economy.

Clay minerals are used to make many items of pottery and dinnerware.

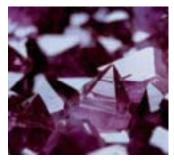
**Brainstorm** Ceramic products can be found at school, at home, and in stores. Make a list of ceramic products that you encounter or use on a regular basis.



# **Reviewing Main Ideas**

#### Section 1 Minerals

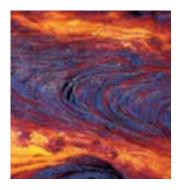
- **1.** Oxygen and Silicon make up almost 75 percent, by mass, of Earth's crust.
- 2. Minerals are naturally occurring, inorganic solids that have a crystalline structure and a predictable chemical composition.



- **3.** Each mineral has characteristic physical properties that help in its identification.
- **4.** Most minerals found in Earth's crust are silicate minerals that contain silicon and oxygen atoms bonded together.

#### Section 2 Igneous Rocks

- 1. Igneous rocks must form from solidification of magma or lava.
- 2. Igneous rocks can be separated into two categories: Intrusive—those that form in Earth—and extrusive—those that form at Earth's surface.



- **3.** Igneous rocks are classified based on their texture and composition.
- **4.** Igneous rocks with granite-like compositions are associated with continental crust, while igneous rocks with basalt-like compositions are associated with oceanic crust.

#### **Section 3 Sedimentary Rocks**

- 1. Sedimentary rocks are consolidated mixtures of minerals, rock fragments, organic debris, or other natural materials.
- 2. Sedimentary rocks can contain or be made entirely of the remains of organisms.



- 3. Detrital sedimentary rocks form through the
  - processes of cementation and compaction.
- **4.** Sedimentary rocks are classified based on clast size and composition.

#### **Metamorphic Rocks and** Section 4 the Rock Cycle

- 1. Metamorphic rocks are made through the effects of heat, pressure, and chemical activity on preexisting rocks.
- **2.** Metamorphic rocks can be divided into two categories: Foliated—having layers or bands—and nonfoliated—with grains in random orientations.
- **3.** The composition of a metamorphic rock depends on its initial composition and the metamorphic processes that occur.
- **4.** The rock cycle describes the processes in Earth that continuously change rocks from one type to another.

FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review Earth materials.

#### **Using Vocabulary**

intrusive igneous cementation p. 625 clast p.624 rock p. 617 cleavage p.610 magma p.613 mineral p. 609 extrusive igneous rock p. 620 pore space p. 625 foliated p. 631 rock p.617 fracture p. 610 rock cycle p. 634 streak p.611 hardness p.611 texture p.617

Match the correct vocabulary terms with each description below.

- 1. molten rock
- 2. grain size and arrangement
- 3. coarse grained
- **4.** scratch resistance
- 5. uneven break
- **6.** consolidated minerals
- **7.** particle of rock
- **8.** layers or bands
- 9. empty space
- 10. fills pore space
- 11. planar break
- 12. natural, inorganic, crystalline solid

#### **Checking Concepts**

Choose the word or phase that best answers the question.

- **13.** What is the most common group of minerals?
  - **A)** carbonates
  - **B)** silicates
  - **c)** sulfates
  - **D)** oxides

- **14.** What is a factor that controls grain size in igneous rocks?
  - A) porosity
  - **B)** cleavage
  - c) cooling rate
  - **D)** temperature
- **15.** What do all the silicate minerals have?
  - **A)** the same hardness
  - **B)** the same crystal structure
  - **c)** silicon and oxygen
  - **D)** silicon and carbon as common elements
- **16.** Through what process does chemical sedimentary rock usually form?
  - A) cementation of sand
  - **B)** compaction of clasts
  - **c)** evaporation of melt
  - **D)** precipitation of crystals
- **17.** Which of the following features are extrusive igneous rocks least likely to have?
  - A) fossils
  - **B)** small grains
  - c) vesicular texture
  - **D)** clasts

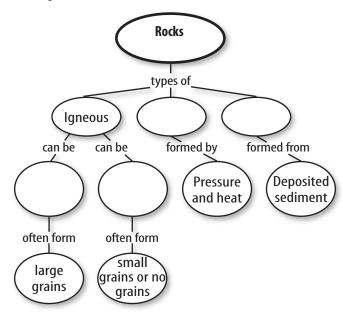
Use the photo below to answer question 18.



- **18.** Which of the following descriptions best describes the large-grained igneous rock shown above?
  - **A)** extrusive and basaltic
  - **B)** extrusive and granitic
  - **c)** intrusive and basaltic
  - **D)** intrusive and granitic

#### **Interpreting Graphics**

**19.** Copy and complete the concept map on igneous rocks.



**20.** Copy the following table on a separate sheet of paper. Use Bowen's reaction series to fill in the blanks.

#### **Crystalization Temperature Ranges** for Mineral 1 and Mineral 2

Temperature Range	Mineral 1	Mineral 2	Rock Name
Low	mica		granite or rhyolite
Intermediate/ High	pyroxene	calcium plagioclase	

#### **Thinking Critically**

- **21. Explain** how cooling rate affects the texture of an igneous rock.
- 22. List the characteristics that help you identify sedimentary rocks.

- **23. Determine** the identity of each rock from the following descriptions.
  - **a.** quartz-rich, coarse interlocking grains, with noticeable amounts of potassium feldspar
  - **b.** foliated mass of mica group minerals with some garnet
  - c. nearly pure mass of fossil shells cemented by calcite
  - **d.** dense black, fine-grained, with some gas bubble holes
  - e. light colored, very low density, frothy (vesicular), glassy

Use the photo below to answer question 24.



**24.** Describe the kind of force and the direction it was most likely applied to produce this foliated metamorphic rock.

#### **Applying Math**

- **25.** If a miner were extracting rock that contained 0.015% gold by mass, how many kilograms of rock must be processed to obtain one kilogram of gold?
- **26.** The body of ore described in question 25 is estimated to have an average density of 6.0 g/cm<sup>3</sup> and contain  $1.5 \times 105 \text{ m}^3$  of ore. How many kilograms of gold potentially could come from this body of ore?

# Standardized Test Practice chapter

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### **Multiple Choice**

- **1.** Which is the most common element in Earth's crust?
  - **A.** aluminum
  - B. oxygen
  - **C.** potassium
  - **D.** silicon

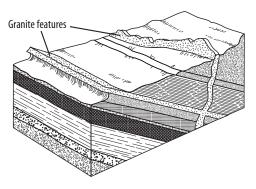
#### Use the image below to answer question 2.



- 2. Which property of a mineral, used in its identification, is shown?
  - **A.** cleavage
  - **B.** fracture
  - **c.** hardness
  - **D.** luster
- **3.** Which is a measure of a mineral's resistance to scratching?
  - **A.** cleavage
  - **B.** hardness
  - **c.** luster
  - **D.** streak

- **4.** Why is graphite used in the core of some pencils?
  - A. Its hardness is high enough to leave a scratch on paper.
  - **B.** Its hardness is low enough to leave a streak on paper.
  - **C.** Its metallic luster gives it a dark color.
  - **D.** Its metallic luster makes it shine on paper.
- **5.** Which mineral is very important to the production of machinery for manufacturing goods?
  - **A.** feldspar
  - B. halite
  - **C.** hematite
  - **D.** quartz

#### Use the photo below to answer question 6.



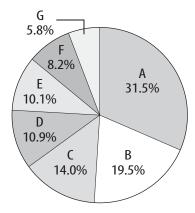
- **6.** The formation of which type of rock produced the granite features shown above?
  - **A.** foliated metamorphic rock
  - **B.** extrusive igneous rock
  - **C.** intrusive igneous rock
  - **D.** nonfoliated metamorphic rock

- 7. Which is a dark-colored igneous rock with small grains?
  - A. basalt
  - **B.** gabbro
  - **C.** granite
  - **D.** rhyolite

#### **Gridded Response**

**8.** If the percent by mass of silicon in Earth's crust is 27.7 percent and the percent by mass of iron is 5.0 percent, how much more silicon is present in Earth's crust than iron?

Use the circle graph below to answer question 9.



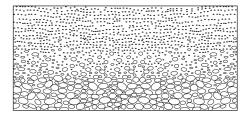
**9.** The percent by mass of elements in Earth's crust are: 46.6% oxygen; 27.7% silicon; 8.1% aluminum; 5.0% iron; 3.6% calcium; 2.8% sodium; 2.6% potassium; 2.1% magnesium; and 1.5% all others. When oxygen and silicon are not considered, the relative abundance of the remaining elements in Earth's crust are shown in the circle graph above. Which material represents the abundance of calcium?

#### Short Response

- **10.** How does coal form? Describe the initial material, deposition environment, and geological conditions that lead to its formation.
- 11. Describe the rock cycle. Discuss what can happen to rock material within the cycle and the amount of time it might take for rocks to be transformed.
- **12.** How does a mineral crystal grow during mineral formation?
- **13.** What are some of the factors that affect the way a crystal grows?

#### **Extended Response**

Use the illustration below to answer question 14.



- **14. PART A** Describe how the sediment particles are arranged in the illustration above.
  - **PART B** Describe the type of environment in which this arrangement of sediment particles might occur.

#### **Test-Taking Tip**

**Review** Double check your answers before turning in the test.

# 21

#### BIG (Idea

Rocks on Earth's surface are broken down into small particles that are transported from place to place.

#### 21.1 Weathering and Soil

MAIN (Idea Weathering breaks down rocks at Earth's surface into smaller particles.

# 21.2 Shaping the Landscape

MAIN (Idea Materials are transported by erosion over Earth's surface and deposited.

#### 21.3 Groundwater

MAIN (Idea) Water can penetrate into the ground and be stored in porous rocks.

#### 21.4 Geologic Time

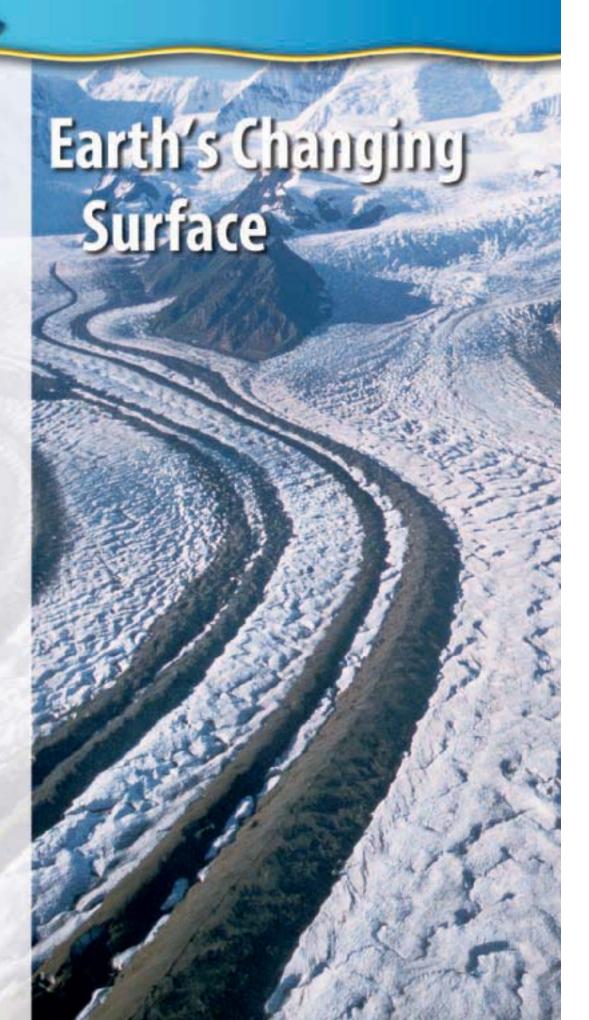
MAIN (Idea Relative dating and absolute dating are used to infer Earth's history.

#### Carving a Path

This glacier is a river of ice that is flowing slowly over Earth's surface. Just as flowing water does, glaciers also change the surface over which they move. Glaciers can carve valleys and leave hills, ridges, and lakes when they melt.

#### **Science Journal**

In your Science Journal, describe how a river can change the land over which it flows.



# **Start-Up Activities**



#### Have you got the time?

We usually think of time in terms of hours, days, and years. Earth processes operate in much longer time units. Imagine that Earth's age—about 4.5 billion years—were equal to an average human lifespan of 75 years. Then one million years of Earth's existence would represent about six days of a human life.

- 1. Obtain a 5-m length of adding machine tape and a meterstick.
- **2.** Draw a horizontal line across one end of the tape and label it *Present*.
- 3. Using a scale of 1 mm = 1 million years, draw and label lines across the tape behind *Present* to mark the beginning of each of the following divisions of time:

  Cenozoic Era: 65 million years ago (mya)

Mesozoic Era: 248 mya

Paleozoic Era and beginning of Phanerozoic Eon: 543 mya

Proterozoic Eon: 2,500 mya Archean Eon: 4,550 mya

4. Think Critically Eons are the longest subdivisions of geologic time. An eon is subdivided into eras. Infer why eons and eras are different lengths of time. What kind of events might end one time interval and begin a new one?



**Surface Features** Make the following Foldable to help you organize features that result from erosion and deposition on Farth's surface.

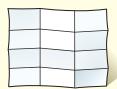
**STEP 1** Fold one piece of paper lengthwise into thirds.



STEP 2 Fold the paper widthwise into fourths.



STEP 3 Unfold, lay the paper lengthwise, and draw lines along the folds.



STEP 4 Label your table as shown.

Surface- Changing Agent	Erosion	Deposition
Wind		
Water		
Glaciers		

**Making a Table** As you read the chapter, complete the table describing erosional and depositional features.



Preview this chapter's content and activities at <a href="mailto:qpescience.com">qpescience.com</a>

# **Weathering and Soil**

## **Reading Guide**

#### What You'll Learn

- Explain the role of weathering in recycling Earth materials.
- Discuss the processes of mechanical and chemical weathering.
- Describe the process of and controls on soil formation.
- Discuss some methods for controlling soil loss.

# Why It's Important

The processes of weathering and soil formation are critical in forming a base to support plant growth and ecosystems.

#### Review Vocabulary

**sediment:** particles of rock deposited on Earth's surface that may become sedimentary rocks

#### **New Vocabulary**

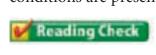
- weathering
- soil

# Weathering

The rocks and other materials that make up Earth's surface are constantly changing. Chemical, physical, and biological processes are continually acting on these materials. These processes cause physical changes and chemical changes to occur. A physical change occurs when the size or shape of an object changes. A chemical change occurs when the chemical compounds that make up a material change. Processes at Earth's surface cause both chemical and physical changes to occur in rocks.

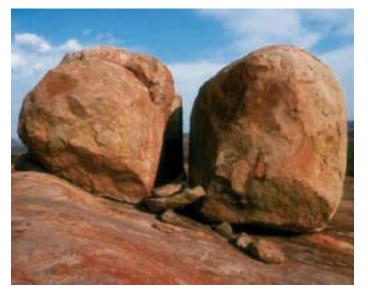
Rocks formed beneath Earth's surface are broken apart when exposed to conditions on Earth's surface. **Figure 1** illustrates the

results of rock weathering. The minerals in this rock formed under higher temperatures and pressures compared to those on the surface. When these minerals were subjected to the conditions at the surface, they broke down. Weathering is the process of physical or chemical breakdown of a material at or near Earth's surface. Factors that influence the amount of weathering include the agent, such as water or air, the nature of the material being weathered, climate, and time. Weathering varies from region to region because different weathering conditions are present.



Reading Check What causes weathering?

**Figure 1** The corners and edges of rocks are more rapidly weathered than smooth rock faces. This often produces rounded forms.



**Everyday Weathering** You can notice weathering going on all around you. Paint on a house eventually will crack or fade in color. Roadways eventually develop cracks and potholes. Some metal items on cars might start to rust. All of these take place at different rates depending on where you live and whether or not you have taken measures to prevent weathering.

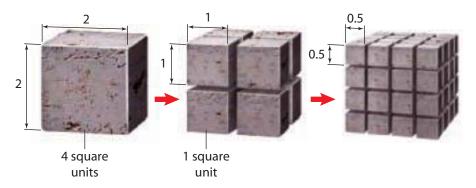
# **Mechanical Weathering**

Mechanical weathering occurs when rocks are broken into smaller pieces without changing their chemical composition. Physical forces exerted on rocks cause mechanical weathering to occur. These forces can be caused by collisions when rocks fall from a cliff or roll down a slope. Other processes, including frost wedging and biological activity, can exert forces that break rocks into smaller pieces.

As **Figure 2** shows, when a large particle breaks into smaller particles, the total surface area of all the particles increases. The increased surface area enables chemical weathering, discussed on the next page, to further reduce the particle size more quickly.

**Frost Wedging** Rocks on Earth's surface can be broken apart by frost wedging. Frost wedging occurs when water collects in the cracks in a rock and then freezes. When the water freezes, it expands and pushes the crack apart. When the water melts and then freezes again, the crack is pushed farther apart. After a number of freeze-thaw cycles, the crack can become large enough to break the rock.

**Biological Activity** Plant roots growing in cracks in rocks can exert forces that break the rocks apart. As the plant root grows, it expands and exerts a force on the surrounding rock. This force can be strong enough to widen the crack and make it longer. When the crack becomes long enough, the rock splits apart.





#### **Observing a Disappearing Seasoning**

#### **Procedure**

- 1. Sprinkle a teaspoon of sugar on a paper plate. Using the back of a metal spoon, crush the sugar into the finest powder you can. Do the same for a teaspoon of salt.
- 2. Half-fill four clear drinking glasses with tap water. Allow them to stand for several minutes.
- 3. Have a watch with a second hand ready. Drop a teaspoon of uncrushed sugar into a glass of water and stir. Record how long it takes the sugar to completely dissolve.
- 4. Repeat step 3 using the powdered sugar, the powdered salt, and a teaspoon of uncrushed salt.

#### **Analysis**

- 1. Which substance dissolved fastest? Why?
- 2. How does particle size affect dissolving rate?
- **3.** List some variables other than particle size that could affect dissolving rate.

**Figure 2** The cube on the right has exposed, inner surfaces that the cube on the left does not have.



Illegible Rocks The Egyptians carved tall, slender granite obelisks. One is displayed in New York City and another in London. Over time, these two obelisks have become almost smooth and the hieroglyphs barely can be seen. Form a hypothesis stating why the obelisks changed.

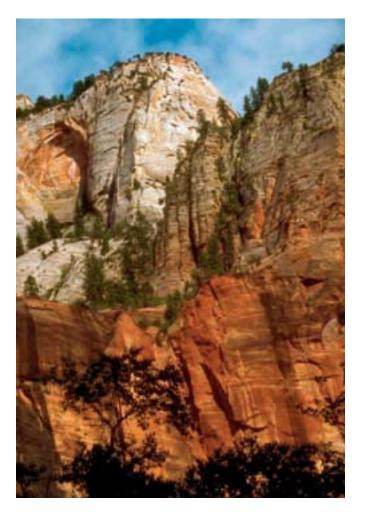
# **Chemical Weathering**

Chemical weathering is the breakup of rocks caused by chemical reactions that form new minerals and other materials. Chemical weathering is caused mainly by chemical reactions of rocks with water, oxygen, and naturally occurring acids. The process of chemical weathering produces chemical compounds that are released into the environment. Some of these compounds are nutrients that plants need to grow.



List three materials that cause chemical weatherina.

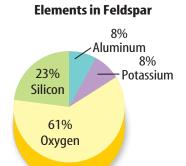
Chemical weathering also affects marine environments. Some chemical compounds produced by the chemical weathering of rocks can be dissolved in water, where they form ions. These ions can be carried by rivers and streams into Earth's oceans, where they are used by marine organisms. For example, marine organisms that build shells require dissolved materials such as calcium ions (Ca<sup>2+</sup>) and bicarbonate ions (HCO<sub>3</sub><sup>-</sup>) to make their shells. These ions come from the weathering of limestone on land and from the dissolving of other seashells.

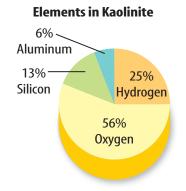


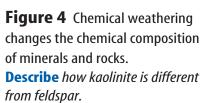
**Oxidation** The chemical reaction of oxygen with other chemical compounds is called oxidation. Steel rusts when it is exposed to air and water due to the oxidation of iron atoms in the steel. Similarly, iron atoms in minerals react with oxygen to form compounds called iron oxides. For example, the mineral hematite contains iron oxides produced by oxidation reactions. Hematite is mined to obtain iron for steel production.

The red or brownish-red color of some rocks, such as the rocks shown in **Figure 3**, is due to the presence of hematite. Some soils also have a reddish color. These soils contain particles that were formed by the chemical weathering of rocks containing iron. Iron oxides in these particles gives the soils their reddish color. Other minerals that form iron oxides are magnetite, pyrite, hornblende, and biotite.

**Figure 3** When iron-bearing rocks are weathered and eroded, they often produce reddish sediment. Iron oxidation also can give some soils a reddish color.











Feldspar reacts with carbonic acid.

The mineral kaolinite is formed.

**Feldspar Weathering** An important chemical weathering process for continental rocks is the weathering of feldspar minerals into clay minerals.

This reaction starts with a common rock-forming mineral shown in Figure 4, and ends with minerals that are common in continental sediment and soil. The silica end product often forms quartz cement in sedimentary rocks. The kaolinite is a clay mineral that helps soil hold water and nutrients. Some of the chemical compounds released by process are used by plants. Similar chemical weathering processes help break down other types of minerals. These processes provide nutrients needed for plant growth and help produce small particles of soil.

**Differential Weathering** Different rock formations tend to weather at different rates. The types of minerals, cementing agent, and the presence of defects, such as fractures, influence how a rock formation weathers. As a result, rock formations that are the most resistant to weathering remain in the landscape. They are products of differential weathering and erosion.

Together, erosion and deposition of sediment create a variety of landforms. They also are important processes in the rock cycle. Landforms, such as those in Figure 5, are geologists' clues to the processes taking place on Earth's surface. Some of these processes include floods, landslides, and beach erosion.

**Figure 5** Erosion and deposition caused by the flow of water produced these landforms.



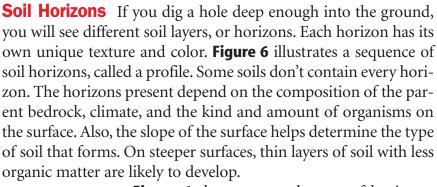
#### Soil

One natural resource that is vital to life on Earth is soil. **Soil** is a mixture of weathered rock, organic matter, water, and air that is capable of supporting plant life. The organic matter in soil comes from plants, animals, and other organisms. Soil originates from weathering of the bedrock beneath it or from materials transported from another location. The raw materials for soil continuously form through the weathering of bedrock below and the addition of organic matter from above.

Reading Check | Soil is made up of what?

**Figure 6** This illustration provides a generalized view of a soil profile. Soil horizons vary in color and thickness. Some horizons don't appear in certain soils. Notice that the E horizon is lighter in color than the B horizon.

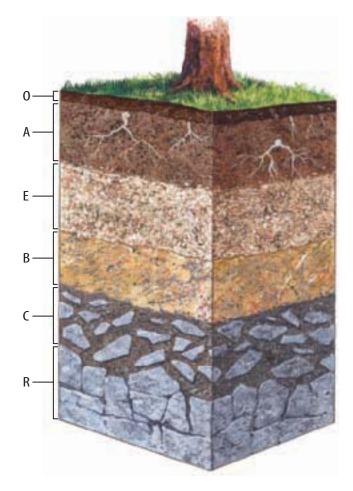
**Explain** why the E horizon is light in color.

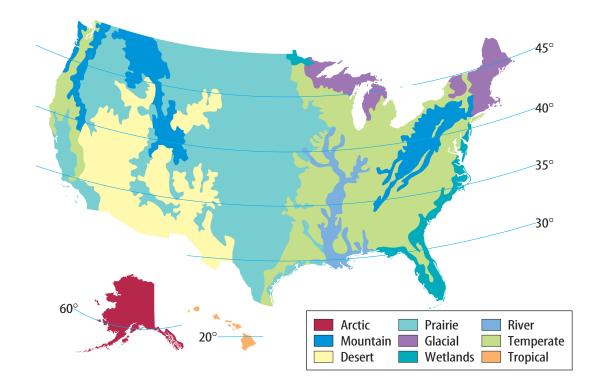


**Figure 6** shows a complete set of horizons, designated as O, A, E, B, C, and R from the surface to bedrock. The O horizon, for organic, and the A horizon often are referred to as topsoil. Plants get most of their nutrients from the topsoil.

The E horizon, for eluviation, is a zone in which finer sediments and soluble materials are transported downward. The process of dissolving soluble elements and transporting them deeper into the soil is called leaching. This is much like a coffee maker that leaches flavors from ground coffee. The B horizon collects the materials from above and is usually darker than the E horizon. Sometimes so much material accumulates that water can't easily penetrate this zone. This formation is referred to as hardpan. The E horizon and the B horizon often are referred to as subsoil. Roots from large trees sometimes penetrate these horizons to get water and are able to anchor themselves in the subsoil.

Collectively, horizons O, A, E, and B make up the true soil. The C horizon is partially crumbled and weathered bedrock. The R horizon is unweathered bedrock.





**Soil Types** There are many different types of soil. Climate types are often used to classify many different types of soil, as illustrated in **Figure 7.** Soils are classified by their composition and physical properties. The amount of precipitation and the temperature range of a region, together with the types of rock, affect the soil that forms. Vegetation, if present, also is important for providing a supply of organic matter. For example, topsoils that develop beneath the forests of the eastern U.S. are acidic, sandy in texture and light in color. This contrasts with soils that develop beneath the grasses of the western U.S. These often are enriched in calcite and are whitish in color. In tropical environments, the soils are strongly leached. They are rich in insoluble aluminum, iron oxides, and clay minerals. Finally, in the arctic or desert regions, where little or no vegetation grows, there is little or no soil. Without organic material, a true soil cannot develop.

**Parent Material** The materials from which a soil forms are called parent materials. Some soils form from parent materials that have been transported from distant sources. Rivers and glaciers are important transporting agents for soils. Some of the most fertile soils form when rivers flood and deposit new sediment on floodplains or when glaciers transport and deposit sediment. The ancient Egyptians relied for thousands of years on the annual flooding of the Nile River to deposit nutrient-rich sediment. During the most recent ice advance, glaciers in North America transported materials that later would become some of the world's most fertile soils.

Figure 7 Glacial soil in the northeastern U.S. often is composed of poorly-sorted glacial till. The eastern U.S. receives large amounts of precipitation which contribute to wetland soil.



**Figure 8** The tie-ridging method makes fields look like waffles.

#### **Soil Conservation**

Plants and animals continuously remove nutrients from soil. Soil depletion is a serious agricultural problem in many regions. For example, when the same crop is grown year after year in the same field, particular nutrients are depleted from the soil. Soils in areas with heavy rainfall, such as rain forests, also tend to be deficient in certain nutrients. The continuous recycling of plant matter returns these compounds to rain forest soils.

**Adding Nutrients** Soil depletion is most often corrected by the addition of fertilizers containing nitrogen, phosphorous, or potassium. Farmers often use crop rotation to help preserve the quality of soils. This is because what one crop removes from the soil, another crop may return. For example, some crops, such as legumes, return nutrients to the soil. Crop rotation also helps prevent erosion and reduces the risk of plant diseases and attack by pests. Another alternative is to allow the soil to rest, or go fallow, by not planting crops. This gives the soil time to replenish some of its lost nutrients.

**Preventing Soil Loss** Most soil lost to erosion occurs because the vegetative cover has been removed or because the land is overly steep. Modern farmers use contour plowing, which runs the furrows around a hill instead of up and down a slope, to reduce erosion. In the tie-ridging method, shown in **Figure 8**, crops are planted on ridges and rainfall collects in basins. Slowing the downhill flow of water helps prevent erosion.

#### section

# 1

#### review

#### Summary

#### **Mechanical and Chemical Weathering**

- Weathering is the breakdown of materials that are not stable under the physical conditions at Earth's surface.
- Physical breakdown of surface materials is accomplished by mechanical weathering.
- Chemical reactions at Earth's surface change mineral composition and release elements.

#### **Soil and Soil Conservation**

- Soil is a mixture of organic matter, weathered rock material, water, and air.
- Measures are taken to prevent soil depletion and soil erosion.

#### **Self Check**

- **1. Explain** how mechanical and chemical weathering processes are related.
- 2. Describe how the controls on soil formation affect soil.
- 3. Distinguish between soil depletion and soil erosion.
- 4. Think Critically Outline the soil conservation measures you expect from any contractor building new roads in your region.

#### **Applying Math**

**5. Calculate** Suppose that soil erosion in your area averages 2.65 cm per year. The average soil profile is 3 m thick, and 45 percent of that is topsoil. Estimate how long it will take for the topsoil to erode.



# Graphing Soil Textures

Three particle sizes characterize the textures of most soils—clay, silt, and sand. The relative amounts of these three variables plot on a triangular graph. In a triangular graph, a corner represents 100 percent of a variable and its opposite base represents 0 percent of that variable.

## Real-World Problem

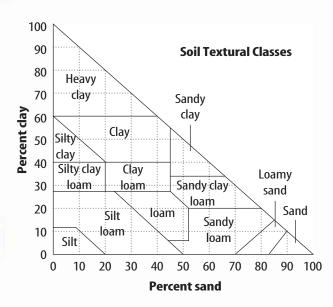
Different plants require different soil textures. How can you classify soil according to texture?

#### Goals

- Graph data on a triangular diagram.
- **Interpret** graphed data to classify soils.

#### **Materials**

soil texture triangular diagram



# Procedure

- **1.** Obtain a copy of a soil texture triangular diagram from your teacher.
- **2.** Find the line representing 40 percent clay.

- **3.** Find the line representing 50 percent sand.
- **4.** Plot the intersection of these two lines on your copy of the graph.
- 5. The remainder of the sample is silt. Your first plotted point represents a soil texture that is 40 percent clay, 50 percent sand, and 10 percent silt, and is called sandy clay.
- **6.** Plot and label the following textures and determine the percentage of silt. Record your answers in a data table.

9	);	ata		
Sample #		% Sand	% Silt	
1	20	40		
2	10	70		
3	15	15		
4	60	20		
5	25	65		

# Conclude and Apply

- **1. Describe** the composition of any soil that plots along the base of the triangle.
- 2. List the texture names for each sample.
- **3. Evaluate** each sample for its ability to retain or drain water.
- **4. Predict** which soil samples would be best for root crops such as potatoes or carrots.

# Communicating Your Data

Prepare a brief oral presentation outlining how to use the soil texture triangle.

# **Shaping the Landscape**

## **Reading Guide**

#### What You'll Learn

- Explain how agents of erosion operate.
- Describe kinds of landforms created by erosion.
- Identify landforms created by deposition of eroded material.

# Why It's Important

Some erosion events, such as floods and landslides, have catastrophic effects on lives and property.

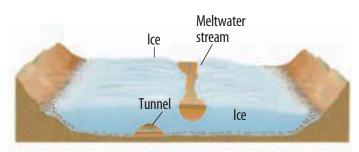
#### Review Vocabulary

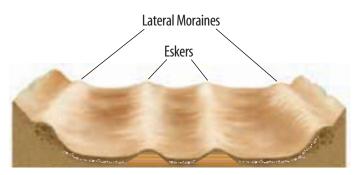
physical change: any change in size, shape, or state in which the identity of a substance remains the same

#### New Vocabulary

- erosion
- sediment transport
- deposition
- drainage basin
- longshore current

**Figure 9** When valley glaciers melt they deposit sediment in characteristic landforms. Moraines consist of poorly sorted glacial till and eskers consist of layers of sorted sediment.



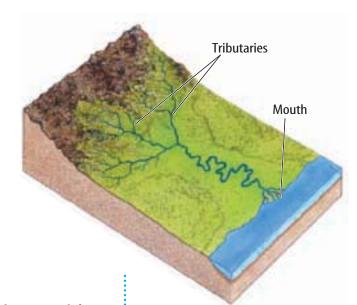


# **Erosion, Transport, and Deposition**

Forces within Earth cause the movement of Earth's tectonic plates. The interactions between plates can cause mountains to be uplifted and produce other landforms on Earth's surface. Although they may seem to be permanent, mountains and other landforms are continually changing. These changes are the result of processes that wear down these landforms. Some of these changes are due to the effects of wind, moving water, and ice. The shape of the land you see is the result of the combined effects of processes that uplift and wear down landforms.

> **Erosion** is the removal of surface material through the processes of weathering. **Sediment transport** is the movement of eroded materials from one place to another by water, wind, and/or glaciers. When a transporting agent drops its load of eroded material, **deposition** occurs. The characteristics of landforms created on the surface, such as the eskers and moraines shown in Figure 9, can help identify the type of agent that formed it. Analyzing the sediment in a surface deposit can reveal clues about where the sediment comes from. For this reason surface sediment often is used to piece together the plate tectonic history of a region.

**Figure 10** Gradient, or slope, affects the shape of a stream and its containing valley. **Compare and contrast** how a steep gradient and a gentle gradient affect the shape of a stream.



# **Running Water**

An important agent of erosion that exerts a downward force on slopes is running water. In steep areas, running water cuts down through sediment and rock, creating V-shaped valleys. As the steepness of a slope decreases, more force is exerted sideways. Lateral cutting broadens river valleys and allows for floodplains to develop. The mouth of a river is where it meets the body of water or land surface into which it ultimately flows. Near the mouth, a river might wind back and forth, or meander, across its valley. Figure 10 shows how characteristics of a river can change as it flows from its source to its mouth.

**Drainage Basins** In most river systems, small streams called tributaries flow into larger streams, which in turn flow into even larger streams. The larger streams finally flow into a major river, such as the Mississippi River. This process of branching is much like a tree with small branches that can be traced to larger

branches, and then to a trunk. All of the land area that gathers water for a major river is the river's drainage basin. Drainage basins are larger in area for major rivers and include all of the drainage basins of its tributaries. The Mississippi River drainage basin extends from the Appalachian Mountains westward to the Rocky Mountains. Both of these mountain ranges represent drainage divides. A drainage divide is a boundary line separating distinct drainage basins. Figure 11 illustrates the Mississippi River drainage basin.

**Figure 11** The Mississippi River drainage basin is the largest drainage basin in the United States.



**Figure 12** This portion of the Colorado River is cutting a deep, V-shaped valley as the Colorado Plateau is being uplifted.



#### **Modeling Runoff**

#### **Procedure**

- **1.** Obtain a clean, flat, smooth **baking sheet.**
- 2. Turn on a faucet and adjust the flow of water to a slow, smooth stream about the diameter of a pencil lead.
- Place the baking sheet at a steep angle under the stream of water. Hold the sheet so that the water runs off along the length of the sheet. Record your observations.
- 4. Make several more observations reducing the steepness each time until your last observation is with the stream perpendicular to the sheet. Record all observations.

#### **Analysis**

What happened to the stream flow pattern as you decreased the angle of the sheet? Explain.

**Figure 13** Streams with many bars within their channels are called braided streams.



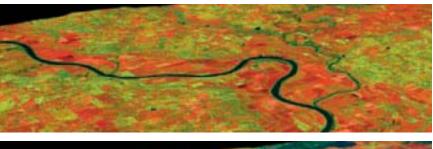
**Channel Development** As surface water flows downhill under the influence of gravity, water erodes the surface, creating its own path or following existing paths called channels. V-shaped valleys are formed from rivers cutting down through sediment and rock, eroding material from a slope. Steep canyons can form when downcutting is rapid. This is often a result of a recent uplift of land, as shown in **Figure 12.** 



What is the shape of a valley that is cut by a young stream?

**Stream Deposits** Maybe you've seen accumulations or bars of sediment in stream channels. When running water slows down, it drops part of the sediment load it is carrying, largest particles first. Generally, bars form on the inside of bends in a river channel, where water speeds are slowest. But in regions where sediment is plentiful, bars might interrupt the flow of water right in the middle of the channel, as shown in **Figure 13**.



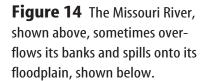


**Floodplains** After a river floods, and as floodwaters subside, slow, and drop their sediment, floodplains form along the valley sides. These floodplains are part of a river, but they are only submerged during floods. Figure 14 shows a satellite image of a portion of the Missouri River before and during the 1993 flood. While they can be catastrophic to property, a beneficial effect of such a flood event is to add nutrients to the soil.

**Deltas** At the mouth of a stream that empties into a body of water, a fan-shaped sediment deposit called a delta will form. Deltas often have branching channels, like roots of a tree, called distributaries. Distributaries distribute water and mud into the water body they enter, as shown in Figure 15. Similar depositional features, called alluvial fans, form where the mouth of a stream enters dry land.

Figure 15 Both tributaries and distributaries are sometimes compared to branches or roots of a tree. Some distributaries of the Mississippi River are shown here.

**Compare and contrast** *tributaries and* distributaries.





#### **Topic: Bayou**

Visit **gpescience.com** for Web links to information about the Louisiana Bavous.

**Activity** A bayou can be a creek, secondary watercourse, or any of various, usually marshy or sluggish bodies of water. Research the origin of the word bayou. Locate the Louisiana Bayous on a United States map.





**Topic: Isostatic Rebound** Visit **gpescience.com** for Web links to information about the effect of the weight of glacial ice on Earth's crust.

**Activity** In your Science Journal, describe evidence that supports the fact that Earth's crust rebounded upward at a location where the weight of glacial ice was removed.

**Figure 16** Valley glaciers create a variety of alpine, or mountainous, features. Along their paths, they accumulate soil and surface rocks that become abrasive material used to transform the landscape.

**Compare and contrast** *trunk val*leys and hanging valleys.

#### **Glaciers**

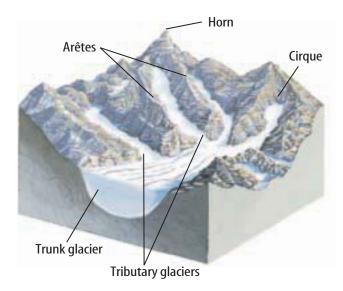
For a glacier to form, the amount of snow that falls in the winter must not be completely melted over the rest of the year. Then over thousands of years, the accumulated snow becomes thick enough for glacial ice to form by compaction due to the weight of the top layers of snow. Valley glaciers form at the top, or head, of river valleys in mountainous regions. They move down slope, usually following the path of the preexisting valleys as shown in **Figure 16.** Continental glaciers, or ice sheets, occupy huge land areas. Ice moves away in all directions from the highest areas of the ice sheet.



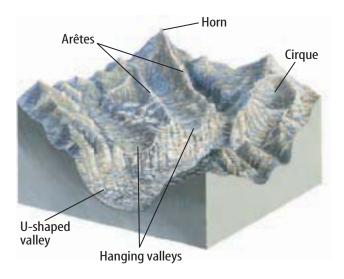
Reading Check What is a requirement for a glacier to form?

When you pour pancake batter onto a griddle, it spreads out under its own weight. Ice sheets flow in the same way. Forces inside the ice due to gravity are large enough to cause the ice to spread out. In some places, water at the bottom of the ice sheet enables the ice to slide over the ground. This is how ice flows in the Greenland and Antarctica ice sheets.

Glaciers become effective agents of erosion as they move either down slope as in valley glaciers or under their own weight as in continental glaciers. As the ice moves, it acts like a giant bulldozer scraping, gouging, and plucking soil and rocks.



Bowl-shaped basins called cirques form by erosion at the start of a valley glacier. Arêtes form where two adjacent valley glaciers meet and erode a long, sharp ridge. Horns are sharpened peaks formed by glacial action at three or more cirques.



U-shaped valleys result when valley glaciers move through regions once occupied by streams. A tributary glacial valley whose mouth is high above the floor of the main, trunk valley is called a hanging valley. The difference between the different valley floors is due to the greater erosive power of the trunk glacier.

**Erosional Features** Valley and continental glaciers leave behind deep grooves or striations, which give clues about the direction the ice was moving. Continental glaciers gouged out the Great Lakes and the finger lakes of New York. Valley glaciers convert V-shaped stream valleys into distinctive U-shaped valleys. The downcutting force of valley glaciers differs from those of streams. Rather than simply cutting downward, glacial ice exerts pressure to the sides as well. This creates the distinct and easily recognized U-shaped valley.

#### What is the shape of a valley that Reading Check is cut by alaciers?

This downward cutting force of ice is a function of mass. Tributary glaciers with less mass cut less deeply. Larger trunk glaciers have more mass and erode more deeply. This produces tributary valleys that enter the main valley at different elevations, creating hanging valleys. Stream divides are eroded into sharp ridges called arêtes. Where ice first accumulates, a bowl-shaped depression called a cirque is

formed. The formation of several cirques around a mountain results in the formation of a horn. Figure 16 illustrates some glacial landforms that form in mountainous areas.

**Glacier Deposits** Ice cannot sort material like moving water does. So, when continental and valley glaciers melt, they dump all the rock material they are carrying. This material, known as till, is composed of random sediment sizes ranging from tiny clay particles to house-sized boulders. The large ridges of till that accumulate at the edge of a glacier are called moraines. An end moraine forms at the front of the ice, and lateral moraines form at the side of the ice. If two valley glaciers join together down slope, their lateral moraines get sandwiched together to form medial moraines. A ground moraine forms underneath melting continental ice sheets.

Some of the smaller-sized particles ranging from clay to gravel are carried away by meltwater and form layered deposits on outwash plains. Deposits of outwash material are layered and sorted by size because of the action of water in transporting and depositing them. Glacial deposits in flat outwash plains often become fertile soils that support plant growth. Figure 17 shows examples of landforms deposited by melting ice.

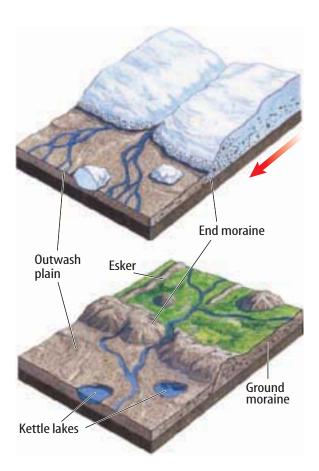
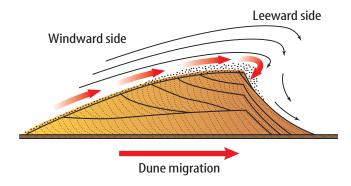


Figure 17 End moraines are composed of poorly sorted soil and rocks that were scraped up by the glacier, moved ahead of it, and then deposited where it melted. Eskers are composed of finer soil and rock material that was sorted and deposited by running water within the glacier.



**Figure 18** Erosion on the windward side and deposition on the leeward side can cause sand dunes to move.

**Infer** Why does deposition occur on the leeward side of a dune?

#### Wind

You might think that wind is the most important agent of erosion in deserts, but this is not so. Running water erodes more, especially during infrequent flash floods. Compared to water and ice, wind cannot pick up and carry large particles. However, wind can act as a sand blaster, blowing sediment around and polishing and smoothing landforms. In places where sand

and smaller particles are abundant and not held in place by vegetation, wind can be a very effective agent of erosion.

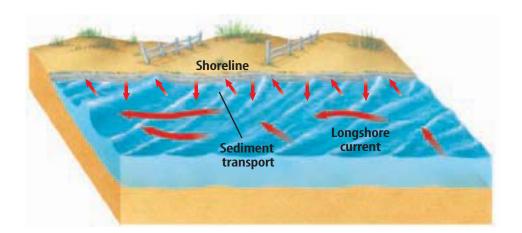
**Erosion by Wind** The removal of small particles by wind, leaving heavier particles behind, is called deflation. Deserts often are pictured as endless sand dunes, but this is misleading. Many deserts have a rocky, rough texture caused by deflation. The remaining surface is known as desert pavement. Blowouts, or deflation hollows, are common landforms where wind is the dominant agent of erosion. These landforms are shallow depressions where wind has scooped out surface material, leaving low places behind.

**Wind Deposits** As wind velocity decreases, the load of sediment is dropped. The shapes and sizes of landforms that form depend on how constant the wind velocity is and on the supply of sediment. Fine silt from glacial outwash plains or deserts is picked up and deposited as thick, unlayered deposits called loess (LUS). Dunes form as the wind moves sand-sized particles into distinct forms, as shown in **Figure 18.** 

#### **Wave Action**

The action of waves on ocean shores can also cause erosion. A cubic meter of water has a mass of 1,000 kg and weighs over a ton. When waves break, the water crashing down on the shore exerts large forces that can change the shoreline.

**Currents from Wave Action** When waves approach a shoreline at an angle, they change directions, or are refracted. They wash up at a slight angle to the beach. The backwash returns to the sea perpendicular to the shoreline. Waves churn up beach sediment, which is carried back toward the sea with the backwash, then moved toward shore at an angle again. This process results in net sediment transport parallel to the shoreline, as illustrated in **Figure 19.** The resulting movement of water parallel to the shoreline is called a **longshore current.** 



**Erosion from Wave Action** The action of waves loaded with sediment works like sandpaper and causes abrasion. This results in rounded pebbles and cobbles on the beach. Coastal cliffs often are eroded at their bases by wave action. This results in periodic collapse of cliff material into the sea. This material then is battered by waves and eventually reduced to smaller sizes that can be transported by the longshore current. Shorelines that are rock-bound with steep cliffs tend to experience differential weathering. A wide variety of landforms, such as sea stacks, sea arches, and headlands, are characteristic of rocky shorelines.

Reading Check How does beach sand become rounded?

**Deposition by Wave Action** Shorelines commonly lack erosional landforms when they have a thick sediment cover. Instead, the sediment on these beaches is constantly reworked producing a variety of depositional landforms. Longshore currents move sediment along the shore. Where this current slows, sediments are deposited as offshore sand ridges or bars. Sandbars run parallel to the shore. A sandbar that seals off a bay from the open ocean is called a baymouth bar. Spits are sand bars that project into the water from land and curve back toward land in a hook shape. Cape Cod is a well-known spit off the coast of Massachusetts. During severe storms, water levels can rise and create sand deposits known as barrier islands that can serve as protection for the mainland. The shallow lagoons between the islands and the mainland are nurseries for many forms of marine life.

# **Mass Wasting**

When erosion occurs primarily as a movement of material down a slope, whether triggered by an influx of water, by earthquakes, or by human activity, mass wasting occurs. Mass wasting takes place where slopes are overly steep or lacking vegetation. Events usually begin when support at the base of a slope is removed and the material above moves downhill.

Figure 19 Longshore currents run parallel to the shoreline. They can completely remove some beaches by erosion and later deposit the sediment, forming new beaches farther down-current.



**Figure 20** In 1985 in Colombia, the Nevado del Ruiz volcano erupted. Meltwater from its glacier-covered peak created a mudflow that took 23,000 lives. In 1991 in the Philippines, Mount Pinatubo erupted and covered its slopes with ash and pyroclastic flows. Heavy rains mixed with the volcanic debris, creating a volcanic mudflow, that covered much of Bacolor Village, shown above.

**Erosion by Mass Wasting** Erosion caused by mass wasting is dependent upon the type of event and the type of materials involved. For example, slumps, which are common in soil along hillsides, produce concave, upward scars from which material has detached and moved downward. Landslides or rockslides also can produce distinct scars on slopes. Mudflows move rapidly and are as dense and damaging as fluid cement. These most often occur following heavy rainfall or snowmelt. **Figure 20** illustrates an example of a mass wasting event.

**Deposition by Mass Wasting** Mass wasting events tend to dump their material in disorganized masses. This material replaces the undermined material at the base of the landform. When sufficient material builds up, the slope becomes stabilized and mass wasting stops. Geologists often can identify ancient landslides by their disorganized structure.

# section

# 2

# review

#### **Summary**

# **Erosion, Transport, and Deposition**

 Features resulting from erosion, transport, and deposition of sediment give clues about the natural processes that formed them.

#### **Running Water and Glaciers**

- Regions along streams have specific characteristics depending on whether they are near the head or near the mouth of the stream.
- Glaciers create characteristic landforms.

#### Wind, Wave Action, and Mass Wasting

- Wind erosion creates landforms such as blowouts and dunes.
- Wave action creates longshore currents.
- Mass wasting occurs when material moves downslope mainly due to gravity.

#### **Self Check**

- 1. **Define** the general process of erosion.
- Describe the process of sediment transport by running water, glaciers, wind, wave action, and mass wasting.
- **3. List** at least two landforms associated with each of processes listed in question 2.
- 4. Think Critically How can you explain a sediment deposit that contains unlayered and randomly sorted material at the bottom and layered, well-sorted material at the top?

# **Applying Math**

**5. Calculate** If a glacier moves 0.5 m per day, how far does it move in 100 years?

# **Groundwater**

# **Reading Guide**

# *What* You'll Learn

- **Explain** the importance of groundwater.
- **Describe** how groundwater is stored and obtained.
- List some concerns about future groundwater use.

# Why It's Important

Groundwater is a main source of drinking water for society.

# Review Vocabulary

porosity: the percentage of open space in a material

#### **New Vocabulary**

- infiltration
- water table
- porosity
- aquifer

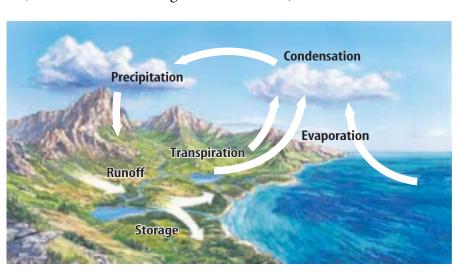
# **Freshwater on Earth**

About 97 percent of all water on Earth is salt water in Earth's oceans. Two percent of Earth's water is frozen as ice in glaciers and ice sheets. The remaining 1 percent is freshwater that is found on land in lakes and rivers or underground as groundwater.

**Water Cycle** Freshwater moves between the atmosphere, land, and oceans in the water cycle, which is shown in Figure 21. The water cycle is the result of repeating cycles of evaporation and condensation and is driven by energy from the Sun. Large amounts of water enter the atmosphere by evaporation from oceans, lakes, and the land. Plants also release some water into the atmosphere through their leaves. This process is called transpiration. Water vapor in the air can condense and form water droplets or ice crystals. Rain, snow, sleet or hail falls to ground

as precipitation, which is freshwater. Most precipitation falls into the oceans. Some of the precipitation that falls on land evaporates or drains into streams and rivers. Some precipitation soaks into the ground and becomes groundwater. **Infiltration** is the process by which water enters Earth and becomes groundwater below the surface.

Figure 21 The water cycle continually redistributes Earth's water.



# **Groundwater**

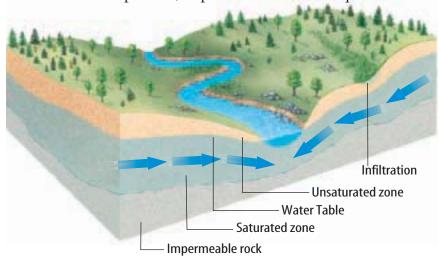
All the water that is naturally stored underground is called groundwater, as illustrated in **Figure 22.** Groundwater is stored underground when water moves underground through infiltration into the pore spaces of sediment and rock. The region near the surface where water can infiltrate freely is the unsaturated zone. The region below that, where water completely fills the pore space, is the saturated zone. The **water table** is the boundary separating these two zones. The rate at which infiltration occurs depends on several factors. These include the type of rock and sediment near the surface, the slope of the surface, and the type and amount of vegetation.

Reading Check | What is the water table?

**The Rate of Infiltration** For infiltration to occur, the rock and sediments beneath the surface must be permeable. This means that water can pass through the material. If the material beneath the surface is permeable and is not saturated, then infiltration can occur quickly. For example, water can pass quickly through unsaturated sand and gravel. However, sediments made of unsaturated clay are much less permeable. As a result, in areas with clay below the surface infiltration occurs slowly.

The slope of the land and the vegetation on the surface also affect the rate of infiltration. If the surface is steep, rainfall or snow melt runs off before it can penetrate the surface layers. Plants also can absorb large amounts of water through their roots before the water can penetrate deeply.

A rock unit that can transmit water through its pore space is called an **aquifer**. Sandstone and limestone often make good aquifers. A rock that slows or stops infiltration is an aquitard. A shale or clay layer makes a good aquitard. Small, local water tables can occur where an aquitard prevents downward infiltration. In this case water is said to be perched, or positioned above an aquitard.



**Figure 22** Groundwater is stored in porous rock called aquifers. It is often recharged, or replenished, by infiltration in wetlands.

**Porosity** Infiltration occurs as water passes through the pore spaces in sediments and rock, as shown in Figure 23. The **porosity** of a material is the percentage of the material's total volume that is pore space. Porosity can be calculated by dividing the total volume of all the pore spaces by the total volume of the material, and then multiplying by 100 percent. In a material, usually some pore spaces are isolated and some pore spaces are interconnected. Water can move through the material only through the interconnected pore spaces. The more interconnected pore spaces there are in a material, the more quickly water moves through the material. A material that is highly permeable has a high porosity and contains many interconnected pore spaces.

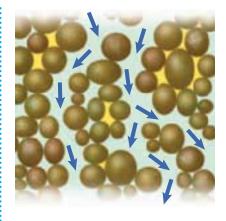


Figure 23 Fluids pass through interconnected pores but cannot pass through isolated pores.

# Applying Math

#### **Use Geometry**

**POROSITY VOLUME** Suppose that an aquifer with dimensions of about 450 km in length and 200 km in width is 75 m thick. It has an average porosity of 7 percent. About how much water can the aquifer potentially hold?

#### **IDENTIFY** known values and the unknown value

#### Identify the known values:

Length of aquifer (L) = 450 km or 450,000 m

Width of aquifer (W) = 200 km, or 200,000 m

Thickness of aquifer (T) = 75 m

Porosity = 
$$7\% = 0.07$$

Identify the unknown value: the porosity volume

#### **SOLVE** the problem

Volume of aguifer =  $L \times W \times T = 450,000 \text{ m} \times 200,000 \text{ m} \times 75 \text{ m}$ 

$$(4.5 \times 10^5 \text{m}) \times (2.0 \times 10^5 \text{ m}) \times (75 \text{ m}) = 6.8 \times 10^{12} \text{ m}^3$$

Total volume of porosity = volume  $\times$  porosity (%)

$$6.8 \times 10^{12} \text{ m}^3 \times .07 = 4.7 \times 10^{11} \text{ m}^3$$

#### CHECK the answer

Does your answer seem reasonable? Check your answer by dividing it by the porosity, thickness, and width values. The result should be the length of the aquifer in meters.

#### **Practice Problems**

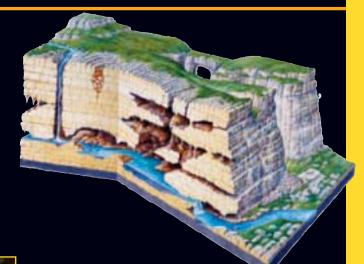
The Dakota Sandstone is 925 km long, 560 km wide, averages 4,200 m in thickness, and has an average porosity of 9.3 percent. What is its water storage volume?

For more practice problems, go to page 879 and visit Math Practice at <a href="mailto:qpescience.com">qpescience.com</a>.

# NATIONAL VISUALIZING THE ROLE OF GROUNDWATER GEOGRAPHIC IN SHAPING EARTH'S SURFACE

# Figure 24

ome of the rainwater that falls on the ground flows into rivers and lakes. However, much of the water flows between soil particles and travels underground. Below ground, acidic water gradually dissolves limestone. Landforms that result from acidic water dissolving underground limestone are known as karst topography. Indications of karst areas include springs, caves, and sinkholes.



Spring waters flow from the ground where the zone of saturation meets Earth's surface. Depending on the level of the water table, springs can be either permanent or intermittent features of the landscape.

Caves form as acidic groundwater flows through bedrock and dissolves limestone. When the water table drops, open channels remain as caves. Limestone caves can extend many kilometers underground and include chambers that are tens of meters high.





Sinkholes can form when the roof of a cave collapses. Sinkholes can range from small, sloping depressions where water can slowly work its way underground, to large chasms where the flow of a stream or river can be transferred to an underground cave.

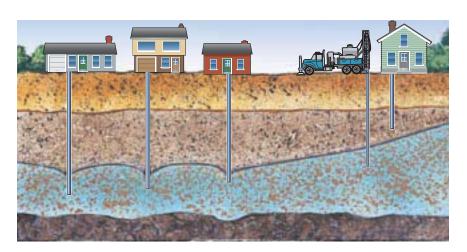
## **Water Resources**

People need freshwater to live. About 50 percent of the population in the United States obtains the freshwater they use from groundwater. Groundwater is also used to irrigate crops and for manufacturing and other industrial purposes.

**Obtaining Groundwater** Some groundwater comes naturally from springs, which occur where the water table intersects the ground surface. Alternatively, wells are holes dug or drilled into Earth. When a drill hole encounters the water table, water can be pumped to the surface. As water is removed from the zone of saturation, the water table is lowered. You might expect the water table's surface to remain horizontal as water is taken away. This does not happen near the well because the groundwater flow path changes.

Much like surface water, groundwater flows downhill. The natural flow path of groundwater has both horizontal and vertical components, as illustrated in Figure 24. Also, groundwater flow rates usually are slow. As water is withdrawn, the direction of water flow shifts downward toward the well, depressing the water table around it into what is called a cone of depression. Depending on the rate of pumping, the cone of depression can affect water availability from other local wells, or force wells to be drilled deeper into an aquifer to obtain water. **Figure 25** illustrates this situation.

Water Under Pressure Wells drilled into aquifers that are under sufficient natural pressure to force water up into a well are called artesian wells. They form when an aquifer is sandwiched between two aquitards. One example might be sandstone positioned between two shale layers. The aguitards keep the water confined to the aquifer. When the aquifer is sloped, gravity on the water provides pressure on the low side of the slope. These wells usually are free flowing at the surface.





Not In My Back Yard (NIMBY) In the past, abandoned mines and parts of uninhabited valleys were used as landfill sites. Trash was thrown into these landfills. When it was discovered that many hazardous materials in trash were leaching into nearby water supplies, something had to be done. Research problems associated with locating sites for landfills and current improvements in landfill technology. Hold a class debate about the pros and cons of landfills.

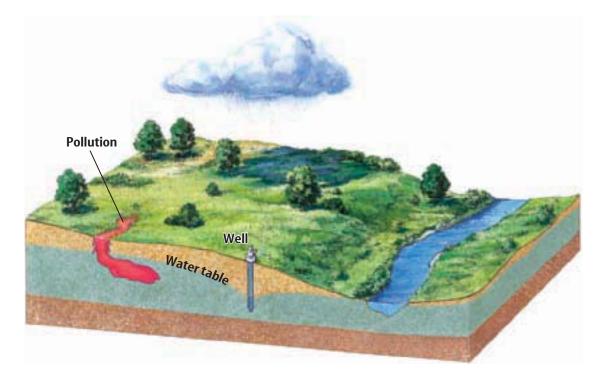


Topic: Hard v. Soft Water Visit **gpescience.com** for Web links to information about the difference between hard and soft water and where they occur.

**Activity** Create a map showing locations of hard and soft water across the United States, Explain what makes water hard or soft and how the effects can be reduced.

Figure 25 As areas become more populated, more water wells often are drilled. This lowers the water table, causing some existing water wells to go dry.

**Infer** Why is a cone of depression created in the water table at the base of a water well?



**Figure 26** Pollution can enter groundwater through infiltration. Cleaning polluted groundwater can be difficult and costly.

**Infer** Why is it important to prevent groundwater resources from being polluted?

**Pollution and Groundwater Resources** Pollutants that are spilled or dumped on the ground and even air pollutants, washed from the air by precipitation, enter groundwater through infiltration, as shown in **Figure 26.** Particles of soil can filter larger contaminants and prevent them from moving deeper. But, natural pollutants such as arsenic can contaminate infiltrated water. Such groundwater is not useful as a freshwater source.



Reading Check How can groundwater become polluted?

# section

# review

# Summary

#### **Water Cycle**

- Only about three percent of Earth's water sources are freshwater. Freshwater is renewed through water cycle processes.
- Supplies of groundwater are replenished when surface water infiltrates into Earth.

#### Groundwater

- The slope of the land, nature of the surface material, and the kind and amount of vegetation control infiltration.
- Porosity and gravity affect how quickly water will move through materials.

#### **Water Resources**

 Both surface and groundwater resources are susceptible to human and natural contamination.

#### **Self Check**

- 1. Explain the importance of groundwater.
- **2. Explain** why pore spaces must be interconnected for water to move through a material.
- 3. Distinguish among the unsaturated zone, the saturated zone, and the water table.
- **4. Think Critically** In a rapidly growing neighborhood, streets, shopping centers, and homes are being built. Discuss the possible long-term effects of such growth on groundwater infiltration and supplies.

## **Applying Math**

**5. Calculate** Suppose a community of 1,500 uses water at a rate of 1,000 L per person per day. This community relies on an aguifer that contains 1.5 billion L of water. How many years will this water supply last?

# **Geologic Time**

# **Reading Guide**

# What You'll Learn

- Distinguish among geologic eras, periods, and epochs.
- **Explain** how scientists decide when a geologic time period ends and another begins.
- **Explain** the methods and logic used in relative dating.
- **Interpret** a geologic cross section.
- **Describe** the methods and logic used in absolute dating.

# Why It's Important

An understanding of geologic time allows you to put current geologic events into a realistic perspective.

# Review Vocabulary

radioactivity: the process that occurs when a nucleus decays and emits alpha, beta, and gamma radiation

#### **New Vocabulary**

- absolute dating
- relative dating
- uniformitarianism
- principle of superposition
- unconformity
- fossil

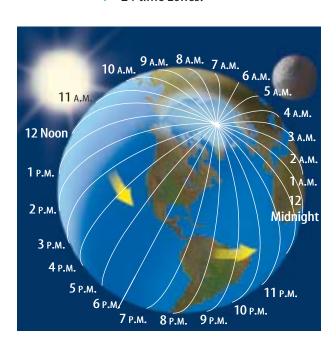
# **Time**

In your daily life you have become accustomed to the length of a year, a day, or an hour. These units of time are ancient and were established by observing astronomical events. Figure 27 shows a globe illustrating Earth's time zones. They are determined by the position of Earth with respect to the Sun during one cycle of Earth's rotation.

**Absolute and Relative Dating** You can give your age in years, months, days, and even hours. To do this you must have a starting reference—your birth date. Birth records often give the exact hour and minute of birth. This is an example of absolute dating. Absolute dating is the process of assigning a precise numerical age to an organism, object, or event. Technology allows scientists to add precision to their findings involving geologic time.

Relative dating is the process of placing objects or events in their proper sequence in time. When you date events relatively, you know which came first, second, and so on. For example, students could be asked to line up in order of birth date, with oldest first. The key to relative dating is that the order is controlled by logical relationships, which might or might not involve the use of numbers.

**Figure 27** Earth is divided into 24 time zones.





It's how old? James Hutton was instrumental in changing the way scientists think about Earth history. Research Hutton's life to discover how a gentleman farmer became such an important scientific figure.

**Uniformitarianism** For many centuries Earth was thought to be thousands of years old. However, in the late 1700s, the Scottish geologist James Hutton proposed that Earth was much older. Hutton's ideas were based on his principle of uniformitarianism, which states that the laws of nature operate today as they have in the past. The only changes might be in their rate or scale. By studying how geologic events take place today, scientists can infer how events took place in the past. Uniformitarianism often is stated "the present is the key to the past." The idea of uniformitarianism is supported by many observations.

# **Principles of Relative Dating**

Geologists use several rules to help determine the relative ages of rock layers. These rules were first proposed in the mid-1600s by Nicolaus Steno, a Danish physician and geologist. Steno's rules enable geologists to determine the sequence in which layers of rock were deposited.

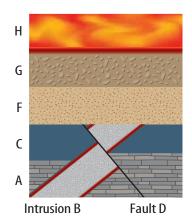
**The Principle of Superposition** One of Steno's rules is the principle of superposition, According to the principle of superposition, in an undisturbed sequence of rock layers, the oldest rocks will be at the bottom of the sequence and the youngest rocks will be at the top.



Reading Check | What is the principle of superposition?

**Original Horizontality** Another one of Steno's rules is the principle of original horizontality. The principle of original horizontality means that sedimentary rock layers are deposited as horizontal or nearly horizontal layers. Sedimentary layers that are flat have not been disturbed since they were deposited. Layers that are tilted or folded have been moved from their initial positions. In the Grand Canyon, layers of rock are horizontal. This means that the layers have not been disturbed since they were deposited. Then according to the principle of superposition, the youngest layers are at the top and deeper layers are older than the layer above them.

**Cross-Cutting Relationships** Steno also observed that sometimes horizontal layers contain rock layers that have cut across, or intruded into, the horizontal layers. According to the principle of cross-cutting relationships, an intrusion is younger than the layers it cuts across. In Figure 28, the intrusion B is younger than the layers A and C.



**Figure 28** The principle of cross cutting relationships often can be used to determine the chronological order of some of Earth's geologic events. This illustration shows an intrusion of igneous rock that was separated later by a fault.

**Unconformities** In some ways, rock layers are like Earth's diary. If you keep a diary, there might be days when you make no entries. There also might be days when you make entries, but later tear them out. Similar things happen as rock layers are deposited. Just as there are days when no entries occur in a diary, there are sometimes gaps in a sequence of rock layers. These gaps occur when no sediments are being deposited. Also, there are times when erosion removes existing rock layers. **Unconformities** are gaps in the rock record during which erosion occurred or deposition was absent. **Figure 29** shows examples of different unconformities.



Reading Check What is an unconformity?

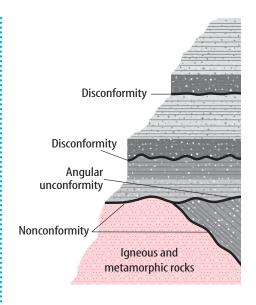
# **Fossils**

The remains or traces of organisms found in the geologic rock record are called **fossils**. Fossils can be direct remains, such as an actual bone or shell. Sometimes fossil remains, such as the inside of a shell, act as molds that form casts when filled with sediment that later hardens to rock. In a process called replacement, water containing dissolved mineral material might replace original shell or bone material with different minerals such as pyrite or quartz. In other cases, only a trace impression such as a footprint or burrow is left for paleontologists to observe.

**Correlation** While working as a canal engineer in England at the end of the eighteenth century, William Smith proposed the principle of faunal succession. Smith noticed that fossils appeared in the same order in the rock layers dug out to build the canals, no matter where he found them. For example, if fossil Q were found in a sedimentary rock layer above fossil F, then Q also appeared above F in a different geographic region. If you apply the law of superposition to this observation, you can conclude that fossil Q is younger than fossil F.

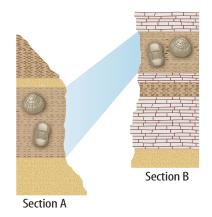
The process of matching distinctive rock units from different regions is called correlation. Figure 30 illustrates how this is done. Paleontologists have been successful in correlating fossilbearing rock units on a global scale. Fossils that are most useful as global time markers often are from organisms that were widespread geographically, but lived in only a narrow, well-defined period of time. Such fossils are called index fossils.

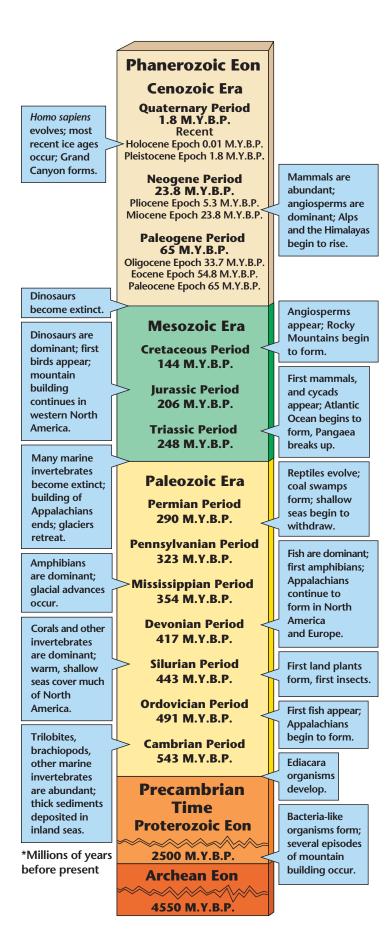
Not all fossil organisms existed over a wide area, however. Some fossils are not useful as time markers because they appear the same over millions of years. In addition, recall that geologic processes such as mountain building and erosion can destroy fossils, making correlation difficult.



**Figure 29** Three types of unconformities are shown above: disconformity, angular unconformity, and nonconformity. A disconformity is an erosional surface between horizontal sedimentary rock layers. An angular unconformity is an erosional surface between rock layer segments that intersect at an angle. A nonconformity is an erosional surface between sedimentary rock and igneous or metamorphic rock.

**Figure 30** Sometimes the relative age of rock units can be found by matching distinctive fossil-bearing rock units from different locations.





Geologic Time Scale Historians speak of the Industrial Revolution, and musicians refer to the Classical Period. These time periods began and ended with some event that marked a noticeable change in society and music. Similarly, paleontologists changes in the fossil record and associate them with boundaries of time units. shown in Figure 31. At these boundaries, fossils of certain life forms are no longer present and new life forms begin to appear. Boundaries also might be established by evidence of a catastrophic geologic event. Such events might have caused environmental changes that led to extinctions or changes in life forms.

# **Absolute Dating**

Absolute dating enables geologists to determine the numerical age of rocks. One type of absolute dating process is based on the radioactive decay of unstable atoms. Recall that isotopes of an element have nuclei with the same number of protons, but different numbers of neutrons. Some isotopes are radioactive and decay into other nuclei by emitting nuclear radiation. The isotope that decays is the parent isotope and the isotope that forms is the daughter isotope.

Some minerals in newly formed igneous rocks have radioactive nuclei that decay. The radioactive materials in the rock start decaying at the time the rock forms. Geologists can measure the ratio of the amount of daughter isotope to the amount of parent isotope to determine the time that has elapsed since the rock formed.

**Figure 31** The geologic time scale is based on the appearance and disappearance of certain types of fossils.

Table 1 Commonly Used Isotopes for Dating Earth Materials				
Radioactive Parent	Stable Daughter	Half-Life		
Carbon-14	Nitrogen-14	5,730 years		
Uranium-235	Lead-207	713 million years		
Potassium-40	Argon-40	1.3 billion years		
Uranium-238	Lead-206	4.5 billion years		
Thorium-232	Lead-208	14.1 billion years		
Rubidium-87	Strontium-87	49.0 billion years		

**Half-Life** Every radioactive isotope has a half-life. The half-life is the time it takes for one-half of a radioactive parent sample to decay to its stable daughter. After one half-life, the ratio of parent atoms to daughter atoms is 50:50, or 1:1. For example, if the half-life of a parent isotope is 500,000 years and a rock is analyzed and the observed daughter/parent ratio is 1:1, one half-life has elapsed and the age of that rock is 500,000 years. During the next half-life, there is decay of one-half of the remaining parent isotope, resulting in one-fourth parent to three-fourths daughter.



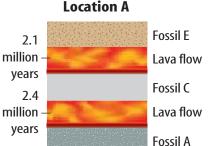
**Useful Isotopes** All of the isotopes in **Table 1** except carbon-14 are common in many types of rocks. Carbon-14 is useful for dating organic Earth materials such as wood and peat.

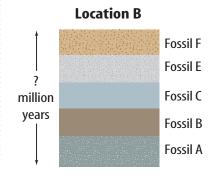
Generally, absolute ages are determined from unaltered minerals in igneous rocks. This is because sedimentary and metamorphic processes involve water or other fluids. When they interact with the rock it can cause the amount of parent isotopes, daughter isotopes, or both to change. When this happens, the age that is determined will be too young or old.

To see how geologists combine relative dating techniques with absolute dating techniques, look at **Figure 32.** You could conclude from the rock layers at Location A that Fossil C is between 2.1 and 2.4 million years old, Fossil A is older than 2.4 million years, and Fossil E is younger than 2.1 million years. These conclusions use radiometric dating for the age values and superposition for the order of events. What age relations can you determine for Fossils C, B, E and F at Location B?

Figure 32 Relative dating and absolute dating techniques can be combined to help determine the ages of some fossils.

**Infer** Why is Fossil C considered to be between 2.1 and 2.4 million vears old?





# **Geologic Maps**

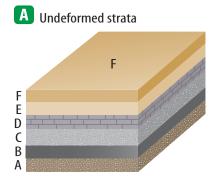
Geologic cross-sections, like the simplified sketch in **Figure 32,** represent a vertical slice taken through Earth. Geologic maps, on the other hand, show the horizontal surface distribution of various rock formations. Most geologic maps also include a legend that indicates the ages of the rock formations at the surface. Geologic maps are two-dimensional models of Earth's crust for a given region. Geologists plot the location, orientation, and boundaries of rocks found at the surface. These data are obtained by direct field observation, through drill cores, aerial photography, and satellite observations.

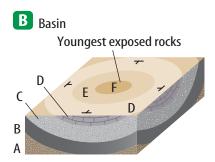


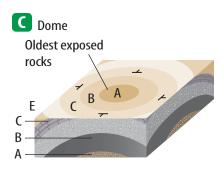
Basins and Domes Recall that rock layers can be deformed by tectonic processes that form faults and folds. One example of a deformed structure is a basin. Recall that the principle of original horizontality states that sediments are laid down in horizontal layers as shown in **Figure 33A.** Compressional forces cause the layers to fold and form a basin. Erosion then removes material from the youngest layers around the edges of the basin. This leaves the youngest layers exposed in the center surrounded by older exposed layers, as shown in **Figure 33B.** 

Domes are the opposite of basins. In this case, the rock layers are uplifted at the center of the structure. Erosion then removes the younger, upper layers of the dome. As a result, older layers are exposed in the center, surrounded by younger layers, as shown in **Figure 33C.** Imagine pushing on opposite sides of a stack of papers to form a dome and then cutting off the top of the dome. The cutting would expose the lower layers of paper in the middle. In this analogy, cutting represents erosion, and the lower paper layers represent the oldest rock layers.

**Folds** Folding of the crust can also be recognized on geologic maps. Recall that compressional stresses tend to squeeze and shorten materials. If the forces on part of Earth's crust are mainly compression forces, then rocks subjected to the compression might wrinkle up or fold. Hold a sheet of paper flat with both hands and push the sides together. The paper wrinkles either up or down. Folds of rock appear much the same way. An upward wrinkle of rock formations is an anticline and a downward wrinkle is a syncline, shown in **Figure 34A.** Push on the paper again, but hold one hand still and push with the other. You get a fold that flops over horizontally. This is called a recumbent fold.

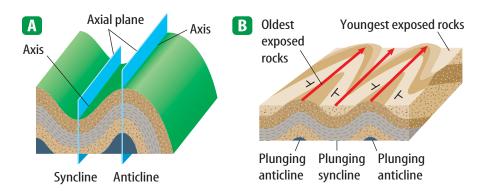






**Figure 33** Tectonic processes can cause Earth's plates to shift, collide, and separate. Sometimes this leads to the deformation of horizontal rock lavers. **Infer** What direction(s) of force

might be needed to create a dome?



**Figure 34** Two basic types of folds are found in rock layers.

- A Synclines form a trough and anticlines form an arch.
- **B** If these folds are tilted, they form plunging folds. On a geologic map, plunging folds appear as V-shaped or horseshoe patterns.

**Plunging Folds** The axis of a fold is an imaginary line where Earth's surface meets the axial plane. The axial plane divides the fold in half, and is usually perpendicular to the compression force. If the forces are applied unevenly the axis of the fold might plunge back into the Earth, producing a surface pattern of rock like the one shown in **Figure 34B.** 

These structural features can give you an idea of how geologists illustrate what the surface of the crust looks like in given locations. Practice viewing the structures in cross section and map view, and apply relative dating logic to the structures. You will soon be able to reconstruct the events that formed the features, and tell a story about their history.

#### section review

## Summary

#### Time

 Uniformitarianism states the processes occurring today are the same as they have been in the past. Rate and extent may have changed.

#### **Principles of Relative Dating**

• Steno's principles help to determine the relative ages of rock layers.

#### **Fossils**

 Fossils are the remains or traces of once-living organisms. Correlation is the matching of rock outcrops from one region to another.

#### **Absolute Dating**

 Analyzing the radioactive decay of radioactive isotopes helps to establish numerical dates for objects and events.

#### **Geologic Maps**

 Geologic maps are two-dimensional models of a region of Earth's crust.

#### Self Check

- 1. Discuss how events in Earth history determine boundaries for geologic time units.
- **2. Compare and contrast** absolute and relative dating.
- 3. **Describe** three lines of logic used in relative dating. Draw and label respective diagrams.
- **4. Think Critically** You're hiking down a canyon that has been deeply eroded, exposing numerous folds. One fold is recumbent, with layers turned completely over. Describe the problems this structure could cause for relative dating, if only a small portion of its rock layers were exposed.

#### **Applying Skills**

**5. Calculate an Age** Suppose the ratio of radioactive parent to stable daughter isotope in a mineral within an igneous rock is 12.5:87.5. The half-life of the parent isotope is  $7.13 \times 10^8$  years. How old is the rock sample?



# It's about timerelative, that is.

#### Goals

- **Observe** geologic cross sections.
- Interpret events that caused the observed features.
- Infer a probable chronology for the events.

#### **Materials**

copies of geologic cross sections

# Real-World Problem

When interpreting the geologic history of a region, geologists follow the principles of relative dating. As with all scientific disciplines, they might get help by exchanging information with other scientists. Some rocks in an area of interest might have been dated using radioactive isotopes or index fossils. How can geologists determine a chronological order of events that took place in a section of Earth's crust over many millions of years?

# **Procedure**

- 1. Familiarize yourself with the symbols in the legend that signify different rock types and other cross section features.
- 2. Examine the cross sections. On your own paper, list the order of events that took place for each cross section, listing the oldest first. Note that the number of steps is not simply the number of rock layers in the cross section.

#### Legend



Limestone



Sandstone



Shale



Conglomerate



Extrusive igneous rock lava flow



Contact metamorphism

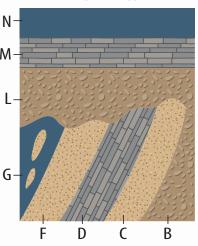


Intrusive igneous rock

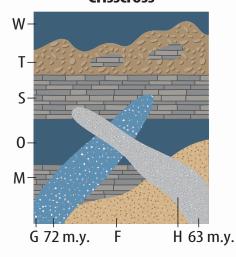


Intrusive igneous rock

#### **Tiltin Hilton**



#### **Crisscross**



# Using Scientific Methods

No fault of mine

**3.** Be sure to include all of the events or actions that changed or helped form the Earth materials shown in each of the four cross sections. For example, unconformities, faulting, folding, or other changes also need to be placed in proper order.

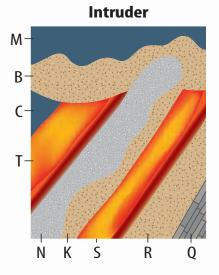
# Analyze Your Data-

- Analyze each cross section and determine whether there is more than one possible chronological interpretation.
- **2. Identify** features that are most useful in supporting relative age relationships.

# 

# Conclude and Apply

- Evaluate cross sections that apparently have more than one possible explanation for a geologic history.
- **2. Explain** whether or not the absolute ages for the intrusions in cross section *Crisscross* agree with the relative ages of the intrusions.
- **3.** How would your answer have changed for cross section *Crisscross* if you did not have absolute age data?
- **4. Summarize** your reasoning for establishing a relative age for fault X in the cross section *No Fault of Mine*.



# Communicating Your Data

Prepare an oral defense for your interpretation of one of the cross sections. Answer questions from classmates who might have made different conclusions about the same cross section.

# TIME

# SCIENCE AND SOCIETY

SCIENCE ISSUES THAT AFFECT YOU!

# Tapping into the underground

reshwater is one of our most important natural resources. Although it may seem that there is an unlimited supply of water—just turn on the faucet and there it is—water supplies can run out. Much of Earth's freshwater is stored in aquifers, inside the cracks and pores of rock and soil. Some of this water flows to the surface and is continually replaced by rainfall that filters through the ground. Other aquifers lie far below the surface, holding water that fell as rain thousands of years ago.

Humans pump water from underground for many uses including drinking, bathing, irrigating crops, and for manufacturing. Because the time needed for water to move into an aquifer can be years or even centuries, these uses consume water faster than it can be replaced by natural processes. When that happens, water is no longer a renewable resource and groundwater shortages become likely.

If water is pumped from a well faster than it can be replaced, the area around it becomes depleted. This results in wells that must be drilled deeper and deeper. Eventually the water flow becomes too slow to be useful. Groundwater shortages don't just affect the amount of water, but they can also affect its quality. Under normal conditions, the direction of underground water

flow tends to be the same as the slope of the surface. As the supply is depleted, water flows from all directions toward the well. In places near the ocean, salt water flowing into the aquifer can make the water useless.

Water conservation—using less water—slows the depletion of the aquifer. This helps the supply refill naturally. Many communities are taking steps to avoid groundwater shortages. In some places, wastewater is cleaned and recycled for other uses to reduce the amount of underground water needed. Another way to use recycled wastewater is to refill the groundwater supply. Treated wastewater is either pumped back into the ground or allowed to filter back into the aquifer from constructed wetlands.



**Interview** Contact a local hydrologist for an interview. Before the interview, do research to determine the sources of water for your community and what happens to treated wastewater. Make a list of interview questions. Conduct the interview and write a summary.

For more information, visit

# **Reviewing Main Ideas**

# Section 1 Weathering and Soil

- **1.** Mechanical weathering reduces the size of materials. Chemical weathering creates new materials or dissolves material through chemical reactions.
- **2.** Differential weathering causes rock that is resistant to particular climate conditions to stand out in the landscape.
- **3.** Soil is composed of weathered rock, decaying organic matter, water, and air. Soil type depends on the nature of the material from which it forms, climate type, and location.



**4.** Erosion and chemical depletion of soil are global problems.

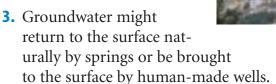
# **Section 2 Shaping the Landscape**

- **1.** Erosion is a set of processes that physically remove material at Earth's surface.
- 2. All the land area that collects water for a major river is a drainage basin.
- **3.** In order to develop, glaciers require long periods of time in which winter snowfall exceeds summer melt. Glaciers create erosional and depositional features.
- 4. Erosion by wind generally is limited to particle sizes that are sand-sized or smaller.
- **5.** Erosion by wave action on rocky coastlines leaves resistant landforms behind, such as sea stacks and arches. Beach erosion and deposition is caused partly by movement of sediment by longshore currents.

**6.** Mass wasting is any form of erosion driven by gravity, such as landslides and mudflows.

#### Section 3 **Groundwater**

- **1.** Groundwater accumulates by the infiltration of surface water. Infiltration is controlled by slope of land, type of surface material, and type and amount of vegetation.
- **2.** Groundwater is stored in aquifers. The movement of groundwater in an aquifer is influenced by gravity, the structure of the aquifer, and by the porosity of the aquifer.





#### **Geologic Time** Section 4

- **1.** Relative dating principles are used to determine the order of geologic events. Radiometric dating uses the decay of radioactive isotopes to establish a numerical age for materials.
- **2.** Geologic maps illustrate the horizontal distribution of rock formations.

FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review Earth's erosional and depositional features.

# **Using Vocabulary**

absolute dating p. 669
aquifer p. 664
deposition p. 654
drainage basin p. 655
erosion p. 654
fossil p. 671
infiltration p. 663
longshore current p. 660
porosity p. 665

principle of superposition p. 670 relative dating p. 669 sediment transport p. 654 soil p. 650 unconformity p. 671 uniformitarianism p. 670 water table p. 664 weathering p. 646

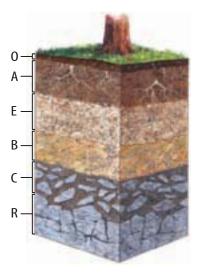
Match the correct vocabulary word(s) with each definition given below.

- **1.** a rock layer that stores and transmits water
- **2.** a means of establishing the order of events
- **3.** region that collects water for a stream system
- **4.** concept that the laws of nature act today as they have in the past
- **5.** a measure of the percentage of a material that is pore space
- **6.** processes of chemical or physical breakdown of a substance
- **7.** Earth's surface covering consisting of weathered rock, decaying organic matter, water, and air
- **8.** boundary separating the saturated zone and the unsaturated zone
- **9.** a surface representing a period of erosion or non-deposition

# **Checking Concepts**

- **10.** What is a process that leaves resistant rock remaining in the landscape?
  - A) deposition
  - **B)** differential weathering
  - **c)** sediment transport
  - **D)** infiltration

Use the illustration below to answer questions 11–12.



- **11.** Which soil horizon contains the greatest amount of organic matter?
  - A) A horizon
  - **B)** B horizon
  - **c)** C horizon
  - D) O horizon
- **12.** Which soil horizon represents weathered bedrock?
  - A) A horizon
  - **B)** B horizon
  - **c)** C horizon
  - **D)** O horizon
- **13.** Which of the following is NOT a typical soil texture component?
  - **A)** gravel
  - **B)** sand
  - c) silt
  - **D)** clay
- **14.** Which of the following is formed by glaciers?
  - A) V-shaped valleys
  - **B)** moraines
  - **c)** flood plain
  - **D)** deltas

- **15.** Select the material that slows or stops movement of ground water.
  - A) aquifer
  - B) aquitard
  - **C)** water table
  - **D)** saturated zone
- **16.** Select the relative principle that states: *The* oldest rock layer is on the bottom.
  - **A)** original horizontality
  - **B)** cross cutting relationships
  - **c)** faunal succession
  - **D)** superposition
- **17.** Which time unit of the geological time scale is the shortest?
  - A) eon
  - **B)** epoch
  - **c)** period
  - D) era

## **Interpreting Graphic**

**18.** Copy and complete the table below.

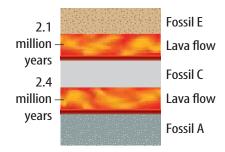
Radioactive Decay				
Half-lives	% Parent	% Daughter		
	50	50		
2				
3				
4				

# **Thinking Critically**

- 19. Explain why a soluble rock such as limestone can stand out as cliffs in the western United States.
- **20.** Infer how water from a natural spring could become contaminated.
- **21.** Infer how lowering the water table could affect springs flowing from a hillside.

- **22. Infer** why cities that draw their water from a drainage basin need to understand how surrounding land is used.
- 23. Infer why rocks or fossils that are found lying on the ground are not useful for relative dating.

Use the illustration below to answer question 24.



- **24. Describe** how absolute dates from ancient lava flows could be used to determine the absolute ages of fossils.
- **25.** Apply The half-life of carbon-14 is 5730 years. Give two reasons why carbon-14 could not be used to date a fossilized bone that was 30 million years old.
- **26.** Apply Explain why glacial deposits made of till are often poorly drained and swampy.

## **Applying Math**

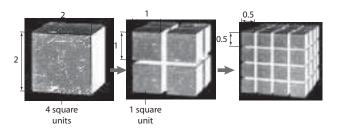
- **27.** Suppose an aquifer is known to be 200 km long and 75 km wide. If its average saturated thickness is 40 m and it has an average porosity of 3 percent, estimate how many cubic kilometers of water could potentially be stored in the aquifer.
- **28.** An igneous rock sample was dated using radioactive potassium. Measurement indicates that 1/32 of the original parent potassium is left in the sample. The halflife of potassium is 1.3 billion years. How old is this igneous rock?

# Standardized Test Practice chapter

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

# Multiple Choice

#### Use the illustration below to answer question 1.



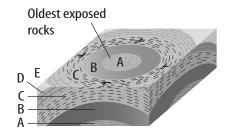
- 1. How does mechanical weathering affect rock material?
  - **A.** alters chemical composition
  - **B.** increases rock surface area
  - **C.** increases rock volume
  - **D.** slows chemical weathering
- **2.** Which is a mixture of weathered rock, organic matter, water, and air?
  - **A.** feldspar
  - **B.** parent material
  - **C.** rock rust
  - D. soil
- **3.** Which is the dropping of sediment load?
  - A. deposition
  - **B.** erosion
  - **C.** transporting
  - **D.** weathering

## **Test-Taking Tip**

Remember Never leave any answer blank.

- **4.** Which develops as force within a stream is exerted sideways?
  - A. floodplain
  - **B.** mouth
  - C. source
  - **D.** tributary

#### Use the illustration below to answer question 5.

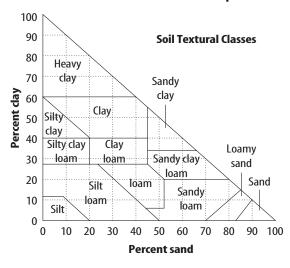


- **5.** Which structural form is illustrated above?
  - A. anticline
  - B. basin
  - **C.** dome
  - **D.** syncline
- **6.** Which is where a stream's water flows into another body of water?
  - **A.** floodplain
  - **B.** mouth
  - C. source
  - **D.** tributary
- **7.** Which forms at the front of a glacier?
  - A. end moraine
  - **B.** ground moraine
  - **C.** lateral moraine
  - **D.** medial moraine

- **8.** Which forms when sand is moved by wind?
  - A. currents
  - B. delta
  - **c.** dunes
  - **D.** loess

# Gridded Response

#### Use the illustration below to answer question 9.



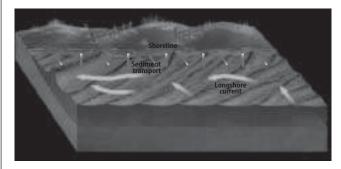
- **9.** What is the greatest percentage of sand that can be in a heavy clay soil?
- **10.** If the half-life of an isotope is 7,000 years and the amount of that isotope present in an igneous rock is only one-fourth of the original amount, how old is the rock?
- 11. Soil erosion in an area is 3.0 cm per year. The soil profile is 2.4 m thick and 25 percent of that is topsoil. How long will it take for the topsoil to erode away?

#### Short Response

- **12.** How does water work to cause mechanical weathering called frost wedging?
- **13.** How does slope affect the soil horizon?
- **14.** Why is vegetation important to the type of soil that forms?
- **15.** What is the drainage basin of a river?
- **16.** How does a delta form?
- 17. How does a bar form on the inside of a bend in a stream?
- **18.** How does a glacier erode the land's surface?

## **Extended Response**

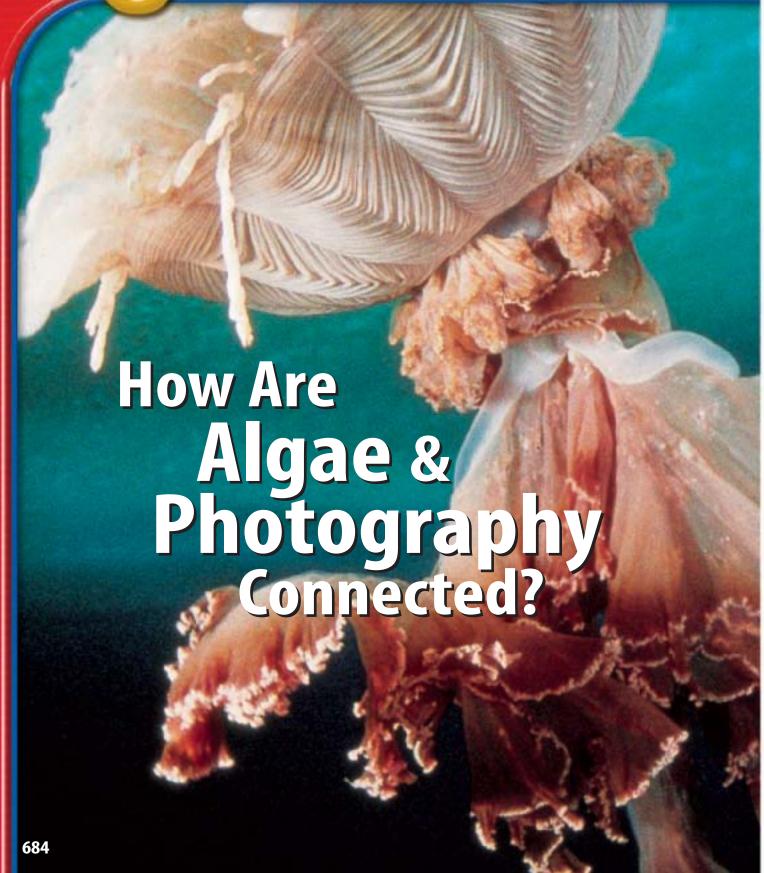
#### Use the art below to answer question 19.



- **19. PART A** How does a longshore current form?
  - PART B Explain how a longshore current affects erosion and deposition.



# Interactions of Matter







22

#### BIG (Idea

Just over 110 elements combine with chemical bonds to form a nearly infinite number of compounds.

#### 22.1 Stability in Bonding

MAIN (Idea When atoms form compounds, each atom is more stable in the compound than it was by itself.

#### 22.2 Types of Bonds

MAIN (Idea Atoms form ionic bonds by transferring electrons and form covalent bonds by sharing electrons.

# **22.3 Writing Formulas and Naming Compounds**

MAIN (Idea The oxidation numbers of the ions in ionic compounds determine the formula of the compounds.

# Elements Form Chemical Bonds

Just like these skydivers are linked together to make a stable formation, the atoms in elements can link together with chemical bonds to form a compound. You will read about how chemical bonds form and learn how to write chemical formulas and equations.

#### **Science Journal**

Rank five materials in order of how hard it is to tear or cut the material. How is the first material on your list different from the last material?



# **Start-Up Activities**



## **Chemical Bonds and Mixing**

You probably have noticed that some liquids such as oil-and-vinegar salad dressings will not stay mixed after the bottle is shaken. However, rubbing alcohol and water will mix. The compounds that make up the two liquids are different. This lab will demonstrate the influence the types of chemical bonds have on how the compounds mix.

- 1. Complete the safety form.
- 2. Pour 20 mL of water into a 100-mL graduated cylinder.
- 3. Pour 20 mL of vegetable oil into the same cylinder. Vigorously swirl the two liquids together, and observe for several minutes.
- **4.** Add two drops of food dye and observe.
- **5.** After several minutes, slowly pour 30 mL of rubbing alcohol into the cylinder.
- **6.** Add two more drops of food dye and observe.
- 7. Think Critically In your Science Journal, write a paragraph describing how the different liquids mixed. Would your final results be different if you added the liquids in a different order? Explain.



**Chemical Formulas** Every compound has a chemical formula that tells exactly which

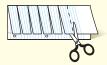
elements are present in that compound and exactly how many atoms of each element are present in that compound. Make the following Foldable to help identify the chemical formulas in this chapter.

STEP 1

**Fold** a sheet of notebook paper vertically from side to side.



STEP 2 Cut along every third line of only the top layer to form tabs.



**Read and Write** Go through the chapter, find ten chemical formulas, and write them on the front of the tabs. As you read the chapter, write what compound each formula represents under the appropriate tab.



Preview this chapter's content and activities at gpescience.com

# **Stability in Bonding**

# **Reading Guide**

# What You'll Learn

- Describe how a compound differs from its component elements.
- **Explain** what a chemical formula represents.
- Explain that the electric forces between electrons and protons, which are oppositely charged, are essential to forming compounds.
- State a reason why chemical bonding occurs.

# Why It's Important

The millions of different kinds of matter around us are a result of chemical bonds.

# Review Vocabulary

compound: substance formed from two or more elements in which the exact combination and proportion of elements is always the same

#### **New Vocabulary**

- chemical formula
- ion

**Figure 1** The difference between the elemental copper metal and the copper compound formed on the Statue of Liberty is striking.

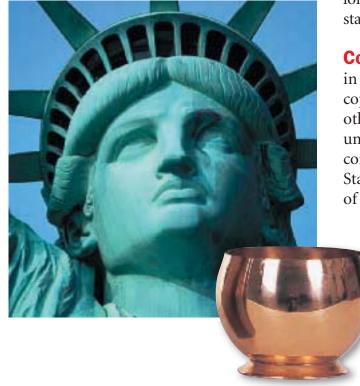
# **Combined Elements**

Have you noticed the color of the Statue of Liberty? It is green. The Statue of Liberty is made of copper, which is an element. Uncombined, elemental copper is a bright, shiny copper color.

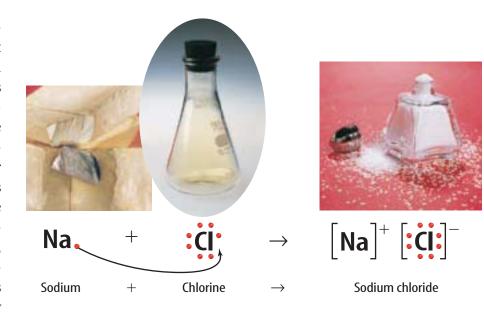
> When copper is exposed to the weather over a long period of time, the metal combines with substances in the atmosphere and changes color.

> **Compounds** Some of the matter around you is in the form of uncombined elements such as copper, sulfur, and oxygen. However, like many other sets of elements, these three elements can unite chemically to form a compound when the conditions are right. The green coating on the Statue of Liberty and some old pennies is a result of this chemical change. One compound in this

coating, seen in contrast with the elemental copper in **Figure 1**, is a compound called copper sulfate. Copper sulfate isn't shiny and copper colored like elemental copper. Nor is it a paleyellow solid like sulfur or a colorless, odorless gas like oxygen. It has its own unique properties.



**New Properties** An observation you will make is that the compound formed when elements combine often has chemical and physical properties that aren't anything like those of the individual elements. Sodium chloride, for example, shown in **Figure 2**, is a compound made from the elements sodium and chlorine. Sodium is a shiny, soft, silvery metal that reacts violently with water. Chlorine is a poisonous greenish yellow gas. Would you have guessed that these elements combine to make ordinary table salt?



**Figure 2** Sodium is a soft, silvery metal that combines with chlorine, a greenish yellow gas, to form sodium chloride, which is a white crystalline solid. **Describe** how the properties of table salt are different from those of sodium and chlorine.

# **Formulas**

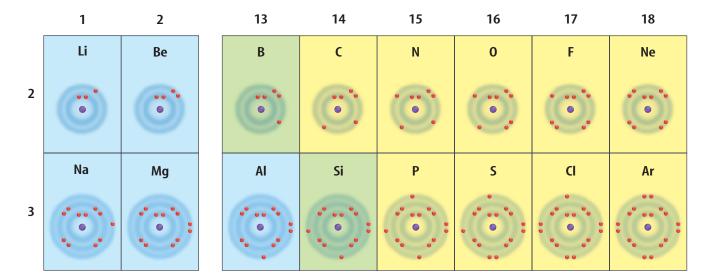
The chemical symbols Na and Cl represent the elements sodium and chlorine. When written as NaCl, the symbols make up a formula, or chemical shorthand, for the compound sodium chloride. A **chemical formula** tells what elements a compound con-

tains and the exact number of the atoms of each element in a unit of that compound. The compound that you are probably most familiar with is H<sub>2</sub>O, commonly known as water. This formula contains the symbols H for the element hydrogen and O for the element oxygen. Notice the number 2 written as a subscript after the H for hydrogen. Subscript means "written below." A subscript written after a symbol tells how many atoms of that element are in a unit of the compound. If a symbol has no subscript, the unit contains only one atom of that element. A unit of H<sub>2</sub>O contains two hydrogen atoms and one oxygen atom.

Look at the formulas for each compound listed in **Table 1.** What elements combine to form each compound? How many atoms of each element are required to form each of the compounds?



Table 1 Some Familiar Compounds		
Familiar Name	Chemical Name	Formula
Sand	Silicon dioxide	SiO <sub>2</sub>
Milk of magnesia	Magnesium hydroxide	Mg(OH) <sub>2</sub>
Cane sugar	Sucrose	C <sub>12</sub> H <sub>22</sub> O <sub>11</sub>
Lime	Calcium oxide	Ca0
Vinegar	Acetic acid	CH <sub>3</sub> COOH
Laughing gas	Dinitrogen oxide	N <sub>2</sub> 0
Grain alcohol	Ethanol	C <sub>2</sub> H <sub>5</sub> 0H
Battery acid	Sulfuric acid	H <sub>2</sub> SO <sub>4</sub>
Stomach acid	Hydrochloric acid HCI	



**Figure 3** The number of electrons in each group's outer level increases across the table until the noble gases in Group 18, where each has a complete outer energy level.

Figure 4 Electron dot diagrams of noble gases show that they each have a stable outer energy level.

He	:Kr:
:Ne:	:Xe:
:År:	:Rn:

# **Atomic Stability**

Why do atoms form compounds? The electric forces between electrons and protons, which are oppositely charged, hold atoms and molecules together, and thus they are the forces that cause compounds to form. The periodic table on the inside back cover of your book lists the known elements. However, the six noble gases in Group 18 do not form compounds, or do so with difficulty. Atoms of noble gases are unusually stable. Compounds of these atoms rarely form because they are almost always less stable than the original atoms.

**The Unique Noble Gases** To understand the stability of the noble gases, it is helpful to look at electron dot diagrams across a period. Electron dot diagrams show only the electrons in the outer energy level of an atom. They contain the chemical symbol for the element surrounded by dots representing its outer electrons. How do you know how many dots to make? For Groups 1 and 2 and 13 through 18, you can use the periodic table or the portion of it shown in **Figure 3.** Elements in Group 1 each have one outer electron. Those in Group 2 each have two. Those in Group 13 each have three, those in Group 14, four, and so on to Group 18, the noble gases, which each have eight.

**Chemical Stability** An atom is chemically stable when its outermost energy level has the maximum number of electrons. The outer energy levels of helium and hydrogen are stable with two electrons. The outer energy levels of all the other elements are stable when they contain eight electrons. Figure 4 shows electron dot diagrams of some of the noble gases. Notice that eight dots surround Kr, Ne, Xe, Ar, and Rn, and two dots surround He.

**Energy Levels and Other Elements** How do the dot diagrams represent other elements, and how does this relate to their ability to make compounds? Hydrogen and helium, the elements in period 1 of the periodic table, can hold a maximum of two electrons in their outer energy levels. Hydrogen contains one electron in its lone energy level. A dot diagram for hydrogen has a single dot next to its symbol. This means that hydrogen's outer energy level is not full. It is more stable when it is part of a compound.

In contrast, helium's outer energy level contains two electrons. Its dot diagram has two dots—a pair of electrons—next to its symbol. Helium has a full outer energy level and is chemically stable. Helium rarely forms compounds and the element is a commonly used gas.

When you look at the elements in Groups 13 through 17, you see that none of the elements has a stable energy level. Each group contains too few electrons for a stable level of eight electrons.



Reading Check Why is it rare for helium to form a compound?

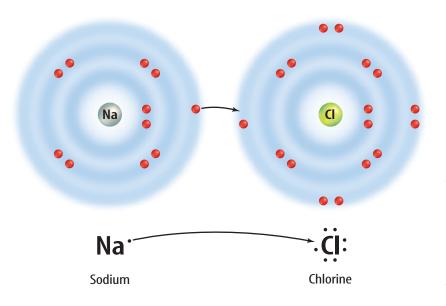
Outer Levels—Getting Their Fill As you just learned, hydrogen is an element that does not have a full outer energy level. How does hydrogen, or any other element, become stable? Atoms with partially stable outer energy levels can lose, gain, or share electrons to obtain stable outer energy levels. They do this by combining with other atoms that also have partially complete outer energy levels. As a result, each becomes stable. Figure 5 shows electron dot diagrams for sodium and chlorine. When they combine, sodium loses one electron and chlorine gains one electron. You can see from the electron dot diagram that chlorine now has a stable outer energy level, similar to a noble gas. But what about sodium?



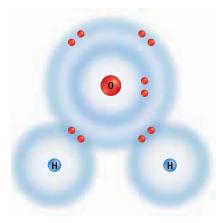
#### **Topic: Dot Diagrams**

Visit **gpescience.com** for Web links to information about using dot diagrams to represent outer energy level electrons.

**Activity** Draw a dot diagram of methane,  $CH_a$ .



**Figure 5** Sodium, as a Group 1 element, will lose one electron. It will have the same number of electrons as neon. Chlorine, which belongs to Group 17, will gain one electron. It will have the same number of electrons as argon. **Identify** the group number where neon and argon can be found.



**Figure 6** In water, hydrogen and oxygen each contribute one electron to each hydrogen-oxygen bond. The atoms share those electrons instead of giving them up.

**Stability Is Reached** Sodium had only one electron in its outer energy level, which it lost when it combined with chlorine to form sodium chloride. However, look back to the next, outermost energy level of sodium. This is now the new outer energy level, and it is stable with eight electrons. When the outer electron of sodium is removed, a complete inner energy level becomes the new outer energy level. Sodium and chlorine are stable now because of the exchange of an electron.

In the compound water, each hydrogen atom needs one electron to have a stable outer energy level. The oxygen atom needs two electrons for its outer level to be stable with eight electrons. Hydrogen and oxygen become stable and form bonds in a different way from sodium and chlorine. Instead of gaining or losing electrons, they share them. Figure 6 shows how hydrogen and oxygen share electrons to achieve a more stable arrangement of electrons.

Atoms, too, lose or gain to meet a goal—a stable energy level. They do not lose or gain an advantage. Instead, they lose or gain electrons. An atom that has lost or gained electrons is called an ion. An ion is a charged particle because it now has either more or fewer electrons than protons. The positive and negative charges are not balanced. It is the electric forces between oppositely charged particles, such as ions, that hold compounds together.

# section

# review

## **Summary**

#### **Combined Elements**

 When elements combine, the new compound has unique properties that are different from the original properties of the elements.

#### **Formulas**

 Chemical symbols and numbers are shorthand for the elements and their amounts in chemical formulas.

#### **Atomic Stability**

- The elements of Group 18, the noble gases, rarely combine with other elements.
- Electron dot diagrams show the electrons in the outer energy level of an atom.
- Most atoms need eight electrons to complete their outer energy levels.

#### **Self Check**

- 1. Compare and contrast the properties of the individual elements that combine to make salt with the compound salt.
- **2. Identify** what the formula BaF<sub>2</sub> tells you about this compound.
- 3. Explain why some elements are stable on their own while others are more stable in compounds.
- **4. Think Critically** The label on a box of cleanser states that it contains CH<sub>3</sub>COOH. What elements are in this compound? How many atoms of each element can be found in a unit of CH<sub>2</sub>COOH?

#### **Applying Math**

5. Use Percentages Given that the molecular weight of Mg(OH)<sub>2</sub>, magnesium hydroxide, is 58.32 g, what percentage of this compound is oxygen?



# At mic Trading Cards

Perhaps you have seen or collected trading cards of famous athletes. Usually, each card has a picture of the athlete on one side with important statistics related to the sport on the back. Atoms also can be identified by their properties and statistics.



# Real-World Problem

How can a visible model show how energy levels fill when atoms combine?

#### Goals

- **Display** the electrons of elements according to their energy levels.
- Compare and classify elements according to their outer energy levels.

#### **Materials**

4-in  $\times$  6-in index cards periodic table

# Procedure

- 1. You will get an assigned element from your teacher. Write the following information for your element on your index card: name, symbol, group number, atomic number, atomic mass, and metal, nonmetal, or metalloid.
- **2.** On the other side of your index card, show the number of protons and neutrons in the nucleus (e.g., 6*p* for six protons and 6*n* for six neutrons for carbon).
- 3. Draw circles around the nucleus to represent the energy levels of your element. The number of circles you will need is the same as the period the element is in on the periodic table.

- **4.** Draw dots on each circle to represent the electrons in each energy level. Remember, elements in row 1 become stable with two outer electrons, while levels two and three become stable with eight electrons.
- **5.** Look at the picture side only of four or five of your classmates' cards. Identify the element and the group to which it belongs.

# Conclude and Apply

- 1. As you classify the elements according to their group number, what pattern do you see in the number of electrons in the outer energy levels?
- 2. Atoms that give up electrons combine with atoms that gain electrons to form compounds. In your Science Journal, predict some pairs of elements that combine in this way.

# Communicating Your Data

Make a graph that relates the groups to the number of electrons in their outer energy levels. For more help, refer to the Science Skill Handbook.

# **Types of Bonds**

# **Reading Guide**

# What You'll Learn

- **Describe** ionic bonds and covalent bonds.
- **Identify** the particles produced by ionic bonding and by covalent bonding.
- **Distinguish** between a nonpolar covalent bond and a polar covalent bond.

# Why It's Important

Bond type determines how compounds mix and interact with other compounds.

## Review Vocabulary

atom: the smallest particle of an element that still retains the properties of the element

#### **New Vocabulary**

- chemical bond
- ionic bond
- covalent bond
- molecule
- polar molecule
- nonpolar molecule

Figure 7 A goiter, an enlargement of the thyroid gland in the neck, can be caused by iodine deficiency.



# **Gain or Loss of Electrons**

You and a friend decide to go to the movies. When you arrive at the theater, you discover that you do not have enough money to buy a ticket. Your friend has enough money for both tickets and loans you the money. Now you both have enough money to go to the movies.

Recall that atoms also can loan electrons to other atoms so that both can reach a stable energy level. When atoms gain, lose, or share electrons, an attraction forms that pulls the atoms together to form a compound. This attraction is called a chemical bond. A chemical bond is the force that holds atoms together in a compound. A compound has different physical and chemical properties from those of the atoms that make up the compound.

Some of the most common compounds are made by the loss and gain of just one electron. These compounds contain an element from Group 1 on the periodic table and an element from Group 17. Some examples are sodium chloride, commonly known as table salt, and potassium iodide, an ingredient in iodized salt.



Why do people need iodized salt? A lack of iodine causes a wide range of problems in the human body. The most obvious is

an enlarged thyroid gland, as shown in Figure 7, but the problems can include mental retardation, neurological disorders, and physical problems.

**A Bond Forms** What happens when potassium and iodine atoms collide? A neutral atom of potassium has one electron in its outer level. This is not a stable outer energy level. When potassium forms a compound with iodine, potassium loses one electron from its fourth level, and the third level becomes the complete outer level. However, the atom is no longer neutral. The potassium atom has become an ion. When a potassium atom loses an electron, the atom becomes positively charged because there is one electron less in the atom than there are protons in the nucleus. The 1+ charge is shown as a superscript written after the element's symbol, K<sup>+</sup>, to indicate its charge. Superscript means "written above."

The iodine atom in this reaction undergoes change as well. An iodine atom has seven electrons in its outer energy level. Recall that a stable outer energy level contains eight electrons. During the reaction with potassium, the iodide atom gains an electron, leaving its outer energy level with eight electrons. This atom is no longer neutral because it gained an extra negative particle. It now has a charge of 1 – and is called an iodide ion, written as I<sup>-</sup>. The compound formed between potassium and iodine is called potassium iodide. The dot diagrams for the process are shown in **Figure 8.** 



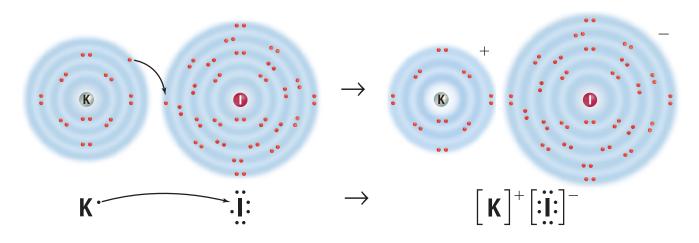
What part of an ion's symbol indicates its

Another way to look at the electron in the outer shell of a potassium atom is as an advertisement to other atoms saying, "Available: One electron to lend." The iodine atom would have the message, "Wanted: One electron to borrow." When the two atoms get together, each becomes a stable ion. Notice that the resulting compound has a neutral charge because the positive and negative charges of the ions cancel each other.



**Ions and Nerve Cells** Ions are important in many processes in your body. The movement of muscles is just one of these processes. Muscle movement would be impossible without the movement of ions in and out of nerve cells. Research the type of ions used by the nerve cells.

**Figure 8** Potassium and iodine must perform a transfer of one electron. Potassium and iodine end up with stable outer energy levels. **Infer** why the size of the ion changes with the change in electron distribution.





**Figure 9** This sparkler contains iron, which burns in air to produce an ionic compound that contains iron and oxygen.

**Figure 10** A magnesium atom gives an electron to each of two chlorine atoms to form MgCl<sub>2</sub>.

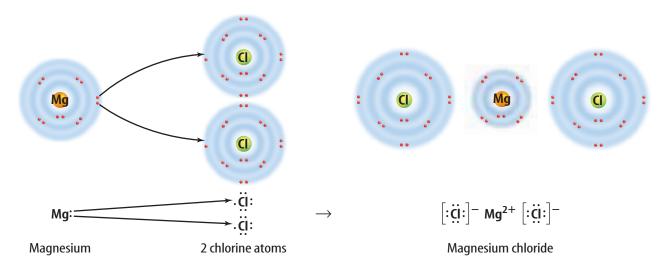
# **The Ionic Bond**

When ions attract in this way, a bond is formed. An **ionic bond** is the force of attraction between the opposite charges of the ions in an ionic compound. In an ionic bond, a transfer of one or more electrons takes place. With this transfer of electrons to form an ionic compound, a large amount of energy is released, as shown in **Figure 9**.

Now that you have seen how an ionic bond forms when one electron is involved, see how it works when more than one electron is involved. The formation of magnesium chloride, MgCl<sub>2</sub>, is another example of ionic bonding. When magnesium reacts with chlorine, a magnesium atom loses two electrons and becomes a positively charged ion, Mg<sup>2+</sup>. At the same time, two chlorine atoms gain one electron each and become negatively charged chloride ions, Cl<sup>-</sup>. In this case, a magnesium atom has two electrons to lend, but a single chlorine atom needs to borrow only one electron. Therefore, it takes two chlorine atoms, as shown in **Figure 10**, to take the two electrons from the magnesium ion to form the compound magnesium chloride.

**Zero Net Charge** The result of this bond is a neutral compound. The compound as a whole is neutral because the sum of the charges on the ions is zero. The positive charge of the magnesium ion is equal to the negative charge of the two chloride ions. In other words, when different atoms form an ionic compound, electrons move from one atom to a different atom, but the overall number of protons and electrons of the combined atoms remains equal and unchanged. Therefore, the compound is neutral.

Metals and nonmetals usually combine by forming ionic bonds. Looking at the periodic table, you will see that the elements that bond ionically are often across the table from each other. Ionic compounds are often crystalline solids with high melting points.



# **Sharing Electrons**

Some atoms of nonmetals are unlikely to lose or gain electrons. For example, the elements in Group 14 of the periodic table have four electrons in their outer levels. They would have to either gain or lose four electrons to have a stable outer level. Losing four electrons takes a great deal of energy. Each time an electron is removed, the nucleus holds the remaining electrons even more tightly. These atoms become more chemically stable by sharing electrons, rather than by losing or gaining electrons.

The attraction that forms between atoms when they share electrons is known as a **covalent bond**. A neutral particle that forms as a result of electron sharing is called a molecule, as shown in **Figure 11.** 

**Single Covalent Bonds** A single covalent bond is made up of two shared electrons. Usually, one of the shared electrons comes from one atom in the bond and the other comes from the other atom in the bond. A water molecule contains two single bonds. In each bond, a hydrogen atom contributes one electron to the bond, and the oxygen atom contributes the other. The two electrons are shared, forming a single bond. The result of this type of bonding is a stable outer energy level for each atom in the molecule.

**Multiple Bonds** A covalent bond also can contain more than one pair of shared electrons. An example of this is the bond in nitrogen  $(N_2)$ , shown in **Figure 12.** A nitrogen atom has five electrons in its outer energy level and needs three more electrons to become stable. It does this by sharing three of its electrons with another nitrogen atom. The other nitrogen atom also shares three of its electrons. When each atom contributes three electrons, they share six electrons, or three pairs of electrons. Each pair of electrons represents a bond. Therefore, three pairs of electrons represent three bonds, or a triple bond. Each nitrogen atom is stable with eight electrons in its outer energy level. In a similar way, a bond that contains two shared pairs of electrons is a double bond. Carbon dioxide is an example of a molecule with double bonds.

Covalent bonds form between nonmetallic elements. These elements are close together in the upper right-hand corner of the periodic table. Many covalent compounds are liquids or gases at room temperature.

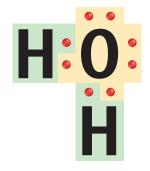


Figure 11 Each of the pairs of electrons between the two hydrogens and the oxygen is shared as each atom contributes one electron to the pair to make the bond.

**Figure 12** The dot diagram shows that the two nitrogen atoms in nitrogen gas share six electrons. **Explain** which of these gases would require the most energy to react with another element to form a compound,  $H_2$  or  $N_2$ .





#### Observing a Bond Type

#### Procedure

- **1.** Complete the safety form.
- Turn on the faucet to produce a thin stream of water.
- **3.** Rub an inflated **balloon** with **wool or fur.**
- **4.** Bring the balloon near the stream of water, and describe what you see.

#### **Analysis**

- 1. Explain your observations.
- 2. Relate the attraction between the balloon and the water to the attraction between the north and south poles of two magnets. Why might water act like a magnet?

**Unequal Sharing** Electrons are not always shared equally between atoms in a covalent bond. The strength of the attraction of each atom to its electrons is related to the size of the atom, the charge of the nucleus, and the total number of electrons the atom contains. Part of the strength of attraction has to do with how far the electron being shared is from the nucleus. For example, a magnet has a stronger pull when it is right next to a piece of metal rather than several centimeters away. The other part of the strength of attraction has to do with the size of the positive charge in the nucleus. Using a magnet as an example again, a strong magnet will hold the metal more firmly than a weak magnet will.

One example of this unequal sharing is found in a molecule of hydrogen chloride, HCl, which is shown in **Figure 13.** In water, HCl is hydrochloric acid, which is used in laboratories and in industry to clean metal, and is found in your stomach, where it helps to digest food. Chlorine atoms have a stronger attraction for the shared electrons than hydrogen atoms do. As a result, the shared electrons in hydrogen chloride will spend more time near the chlorine atom than near the hydrogen atom. The chlorine atom has a partial negative charge, represented by a lowercase Greek symbol *delta* followed by a negative superscript,  $\delta^-$ . The hydrogen atom has a partial positive charge, represented by a  $\delta^+$ .



What determines the strength of attraction of an atom?

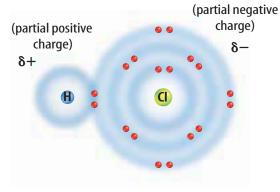
**Tug-of-War** You might think of a covalent bond as the rope in a tug-of-war, and the shared electrons as the knot in the center of the rope. **Figure 14** illustrates this concept. Each atom in the molecule attracts the electrons that they share. However, sometimes the atoms aren't the same size.

The same thing happens in tug-of-war. Sometimes one team has more people or stronger participants than the other. When this is true, the knot in the middle of the rope ends up closer to the stronger team. Similarly, the electrons being shared in a molecule are held more closely to the atoms with the stronger pull or larger nucleus.

**Figure 13** The chlorine atom exerts the greater pull on the electrons in hydrogen chloride, which forms hydrochloric acid in water.

**Explain** why the chlorine atom has a greater pull than the hydrogen atom.

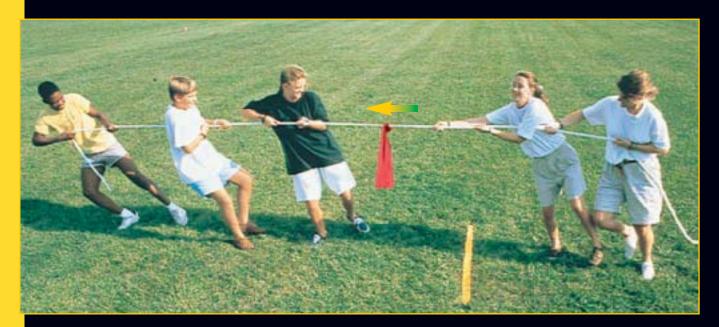


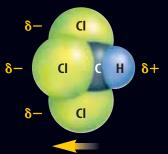


#### **NATIONAL** GEOGRAPHIC VISUALIZING POLAR MOLECULES

#### Figure 14

hen playing tug-of-war, if there are more—or stronger—team members on one end of the rope than the other, there is an unequal balance of power. The stronger team can pull harder on the rope and has the advantage. A similar situation exists in polar molecules, in which electrons are attracted more strongly by one type of atom in the molecule than another. Because of this unequal sharing of electrons, polar molecules have a slightly negative end and a slightly positive end, as shown below.

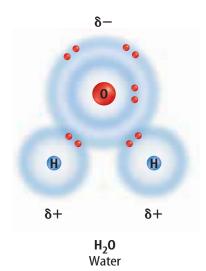




CHLOROFORM In a molecule of chloroform (CHCl<sub>2</sub>), or trichloromethane (tri klor oh ME thayn), the three chlorine atoms attract electrons more strongly than the hydrogen atom does, creating a partial negative charge on the chlorine end of the molecule and a partial positive charge on the hydrogen end. This polar molecule is a clear, sweet-smelling liquid once widely used as an anesthetic in human and veterinary surgery.



**HYDROGEN FLUORIDE** Hydrogen and fluorine react to form hydrogen fluoride (HF). In an HF molecule, the two atoms are bound together by a pair of electrons, one contributed by each atom. However, the electrons are not shared equally because the fluorine atom attracts them more strongly than the hydrogen atom does. The result is a polar molecule with a slightly positive charge near the hydrogen end and a slightly negative charge near the fluorine end.



**Figure 15** The polarity of water is responsible for many of its unique properties. **Explain** the cause of polarity.

**Polar or Nonpolar?** For the molecule involved in this electron tug-of-war, there is another consequence. Again, look at the molecule of hydrogen chloride. The unequal sharing of electrons gives each chlorine atom a slight negative charge and each hydrogen atom a slight positive charge. The atom holding the electron more closely always will have a slightly negative charge. The charge is balanced but not equally distributed. This type of molecule is called polar. The term *polar* means "having opposite ends." A polar molecule is one that has a slightly positive end and a slightly negative end, although the overall molecule is neutral. Water is an example of a polar molecule, as shown in Figure 15.



Two atoms that are exactly alike can share their electrons equally, forming a nonpolar molecule. A **nonpolar molecule** is one in which electrons are shared equally in bonds. Such a molecule does not have oppositely charged ends. This is true of molecules made from two identical atoms or molecules that are symmetric, such as CCl<sub>4</sub>.

#### **Properties of Compounds**

Recall that atoms can form two types of bonds: covalent and ionic. A compound whose atoms are held together by covalent bonds is a covalent compound.

Sugar is a covalent compound. A compound that is composed of ions is an ionic compound. Table salt, NaCl, is an ionic com-

pound. Looking at both substances, you would think they would have similar physical and chemical properties.

Both sugar and salt, as shown in **Figure 16**, are used to change the taste of foods. You add sugar to lemonade or iced tea to make the drink sweet. Table salt is used to enhance the flavors of foods. such as meats and vegetables. Sugar and salt have different physical and chemical properties.

**Figure 16** Table sugar is an example of a covalent compound that is a crystalline solid soluble in water. lonic compounds, such as table salt, are also soluble in water.



Figure 17 Candle wax and propane are covalent compounds that are insoluble in water.

**Covalent and Ionic Properties** The chemical and physical properties of covalent compounds and ionic compounds are different. This difference in properties, as shown in **Table 2**, is due to differences in attractive forces of the bonds.

**Covalent Compounds** The covalent bonds between atoms in molecules are strong. However, the attraction between individual molecules is weak. It is the weak forces between individual molecules that are responsible for the properties of covalent compounds.

Melting and boiling points of covalent compounds are relatively lower when compared to ionic compounds. Sugar will melt at approximately 185°C, whereas table salt will melt at 801°C. Covalent compounds, which will form soft solids, have poor electrical and thermal conductivity. Candles and propane gas shown in **Figure 17** are covalent compounds.

Table 2 Comparison of Covalent and Ionic Compounds			
	Covalent Compounds	Ionic Compounds	
Bond Type	Electron Sharing	Electron Transfer	
Melting and Boiling Points	Lower	Higher	
Electrical Conductivity	Poor	Good	
State at Room Temperature	Solid, liquid, or gas	Solid	
Forces Between Particles	Strong bonds between atoms; weak attraction between molecules	Strong attraction between positive and negative ions	

**Figure 18** Some common ionic compounds used in everyday life are potassium chloride as a salt substitute; potassium iodide added to table salt; and sodium fluoride added to toothpaste.



**lonic Compounds** The ionic bonds between ions are relatively strong. This accounts for the high melting and boiling points of ionic compounds such as table salt. Examples of common ionic compounds are shown in Figure 18. Ionic compounds are hard and brittle. When in a liquid or aqueous state, ionic compounds can conduct electric current.

Strong attractive forces hold the ions in place. Ionic compounds are stable due to the attraction between unlike charges. The ions are drawn together and energy is released. Formation of ionic compounds is always exothermic.



Reading Check Why are ionic compounds brittle?

#### section

#### review

#### **Summary**

#### **Gain or Loss of Electrons**

 An ion is a charged particle that has either fewer or more electrons than protons, resulting in a negative or positive charge.

#### **Ionic Bond**

- An ionic bond is the force or attraction between opposite charges of ions in an ionic bond.
- An ionic compound is neutral because the sum of the ion charges is zero.

#### **Sharing Electrons**

- Some atoms, such as those in Group 4, share electrons instead of losing or gaining them.
- Covalent bonds can form single, double, or triple bonds.
- In a polar molecule, the electrons are shared unequally in the bond. This results in slightly charged ends.
- Electrons are shared equally in a nonpolar molecule.

#### **Self Check**

- 1. Explain why an atom makes an ionic bond only with certain other atoms.
- 2. Compare and contrast the possession of electrons in ionic and covalent bonds.
- 3. Name the types of particles formed by covalent bonds.
- 4. Concept Map Using the following terms, make a network-tree concept map of chemical bonding: ionic, covalent, ions, positive ions, negative ions, molecules, polar, and nonpolar. Define the terms atom and molecule.
- 5. Think Critically Choose two elements that are likely to form an ionic bond: O, Ne, S, Ca, K. Next, select two elements that would likely form a covalent bond. Explain.

#### **Applying Math**

**6. Solve One-Step Equations** Aluminum oxide, Al<sub>2</sub>O<sub>3</sub>, can be produced during space shuttle launches. Show that the sum of the positive and negative charges in a unit of  $Al_2O_3$  equals zero.

# Writing Formulas and Naming Compounds

#### **Reading Guide**

#### What You'll Learn

- **Explain** how to determine oxidation numbers.
- Write formulas and names for ionic compounds.
- Write formulas and names for covalent compounds.

#### Why It's Important

The name and the formula convey information about the compound.

#### Review Vocabulary

anion: a negatively charged ion

#### **New Vocabulary**

- binary compound
- oxidation number
- polyatomic ion
- hydrate

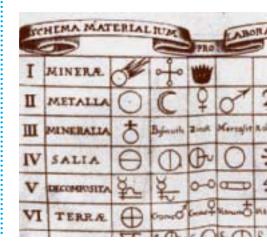
#### **Binary Ionic Compounds**

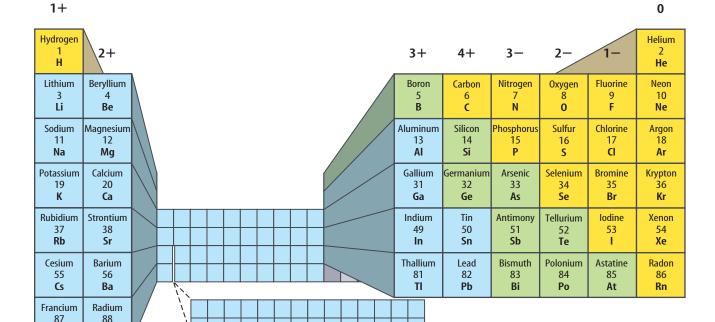
Does the table in **Figure 19** look like it has anything to do with chemistry? It is an early table of the elements made by alchemists, scientists who tried to make gold from other elements. The alchemists used symbols to write the formulas of substances. The first formulas of compounds that you will write are for binary ionic compounds. A **binary compound** is one that is composed of two elements. Potassium iodide, the salt additive mentioned in Section 2, is a binary ionic compound. Before you can write a formula, you must have all the needed information at your fingertips. What will you need to know?

**Oxidation Numbers** You need to know which elements are involved and what number of electrons they lose, gain, or share to become stable. Section 1 discussed the relationship between an element's position on the periodic table and the number of electrons it gains or loses. Because all elements in a given group have the same number of electrons in their outer energy levels, they must gain or lose the same number of electrons. Metals always lose electrons and nonmetals always gain electrons when they form ions. The charge on the ion is known as the **oxidation number** of the atom.

For ionic compounds, the oxidation number is the same as the charge on the ion. For example, a sodium ion has a charge of 1+ and an oxidation number of 1+. A chloride ion has a charge of 1- and an oxidation number of 1-.

**Figure 19** This old chart of the elements used pictorial symbols to represent elements.





**Figure 20** The number at the top of each column is the most common oxidation number of elements in that group. **Define** oxidation number.

Fr

**Table 3 Special Ions Oxidation** Name Number Copper(I) 1+ Copper(II) 2+Iron(II) 2+Iron(III) 3+Chromium(II) 2+Chromium(III) 3+Lead(II) 2+

**Oxidation Numbers and the Periodic Table** The numbers with positive or negative signs in **Figure 20** are the oxidation numbers for the elements in the columns below them. Notice how they fit with the periodic-table groupings.

The elements in **Table 3** can have more than one oxidation number. When naming these compounds, the oxidation number is expressed in the name with a roman numeral. For example, the oxidation number of iron in iron(III) oxide is 3+.

**Reading Check** What is the oxidation number for barium, Ba?

**lonic Compounds Are Neutral** When writing formulas, it is important to remember that although the individual ions in a compound carry charges, the compound itself is neutral. A formula must have the same number of positive ions and negative ions so the charges balance. For example, sodium chloride is made up of a sodium ion with a 1+ charge and a chloride ion with a 1- charge.

However, what if you have a compound such as calcium fluoride? A calcium ion has a charge of 2+ and a fluoride ion has a charge of 1-. In this case, you need to have two fluoride ions for every calcium ion for the charges to cancel and the compound to be neutral with the formula  $CaF_2$ .

Some compounds require more thought. Aluminum oxide contains an ion with a 3+ charge and an ion with a 2- charge. You must find the least common multiple of 3 and 2 to determine how many of each ion you need. You need two aluminum ions and three oxygen ions to have a 6+ charge and, a 6- charge and, therefore, the neutral compound  $Al_2O_3$ .

4+

Lead(IV)

**Writing Formulas** After you've learned how to find the oxidation numbers and their least common multiple, you can write formulas for ionic compounds. Write the formula for an ionic compound containing sodium and oxygen by using the following rules in this order.

- 1. Write the symbol of the element that has the positive oxidation number or charge. Sodium, a Group 1 element, has an oxidation number of 1+.
- **2.** Write the symbol of the element with the negative number. Nonmetals other than hydrogen have negative oxidation numbers. Oxygen has an oxidation number of 2—.
- 3. To have a neutral compound, the positive charges have to balance the negative charges. It takes two sodium ions to balance the one oxygen ion. Thus, the formula becomes Na<sub>2</sub>O.



Jöns Jakob Berzelius As a Swedish chemist, Berzelius is credited with developing the concepts of ions and ionic compounds. Because of his many interests and discoveries in chemistry, Berzelius, like Antoine Lavoisier, is known as one of the founders of

modern chemistry.

#### **Applying Math**

#### **Writing Chemical Formulas**

**DETERMINING A FORMULA** What is the formula for lithium nitride?

**IDENTIFY** known values

Identify the known values:

Symbol and oxidation number of the positive element:

Symbol and oxidation number of the negative element:

SOLVE the problem

To have a neutral compound, it takes three Li<sup>1+</sup> ions to balance the one N<sup>3-</sup> ion.

$$3Li^{1+}=1N^{3-}$$
  $means$   $Li_3N_1$  or  $Li_3N$ 

Reduce the subscripts to the smallest whole numbers that retain the ratios of ions.

CHECK the answer

Does your answer seem reasonable? Check your answer by determining whether your compound is neutral.

#### **Practice Problems**

- **1.** What is the formula for lead (IV) phosphide?
- **2.** What is the formula for iron (III) oxide?

For more practice problems go to page 879, and visit Math Practice at gpescience.com.

Table 4 Elements in Binary Compounds		
Element	<i>-ide</i> Name	
0xygen	oxide	
Phosphorus	phosphide	
Nitrogen	nitride	
Sulfur	sulfide	

Writing Names You can name a binary ionic compound from its formula by using these rules.

- 1. Write the name of the positive ion.
- 2. Using **Table 3**, check to see if the positive ion is capable of forming more than one oxidation number. If the ion has only one possible oxidation number, proceed to step 3. If it has more than one, determine the oxidation number of the ion from the formula of the compound. To do this, keep in mind that the overall charge of the compound is zero and the negative ion has only one possible charge. Write the charge of the positive ion using roman numerals in parentheses after the ion's name.
- **3.** Write the root name of the negative ion. The root is the first part of the element's name. For chlorine, the root is *chlor*-.
- **4.** Add the ending *-ide* to the root. **Table 4** lists several elements and their -ide counterparts. For example, sulfur in a binary compound becomes sulfide.

Subscripts do not become part of the name for ionic compounds. However, subscripts can be used to help determine the charges of these metals that have more than one positive charge.

#### **Applying Science**

#### Can you name binary ionic compounds?

hat would a chemist name the compound CuCl?

#### Identifying the Problem

There are four simple steps in naming binary ionic compounds.

- 1. Write the name of the positive ion in the compound. In CuCl, the name of the positive ion is copper.
- **2.** Check **Table 3** to determine whether copper is one of the elements that can have more than one oxidation number. Looking at **Table 3**, you can see that copper can have a 1+ or a 2+ oxidation number. You need to determine which to use. Looking at the compound, you see that there is one copper atom and one chlorine atom. You know that

the overall charge of the compound is zero and that chlorine only forms a 1- ion. For the charge of the compound to be zero, the charge of the copper ion must be 1+. Write this charge using roman numerals in parentheses after the element's name, copper(I).

- **3.** Write the root name of the negative ion. The negative ion is chlorine and its root is *chlor*-.
- **4.** Add the ending *-ide* to the root, chloride.
- **5.** The full name of the compound CuCl is copper(I) chloride.

#### **Solving the Problem**

- **1.** What is the name of CuO?
- 2. What is the name of AlCl<sub>3</sub>?

#### **Compounds with Polyatomic Ions**

Not all ionic compounds are binary. Baking soda—used in cooking, as a medicine, and for brushing your teeth—has the formula NaHCO<sub>3</sub>. This is an example of an ionic compound that is not binary. Some ionic compounds are composed of more than two elements. They contain polyatomic ions. The prefix *poly*- means "many," so the term *polyatomic* means "having many atoms." A **polyatomic ion** is a positively or negatively charged, covalently bonded group of atoms. Thus, the polyatomic ions as a whole contain two or more elements. The polyatomic ion in baking soda is the bicarbonate or hydrogen carbonate ion, HCO<sub>3</sub><sup>-</sup>.

**Writing Names** Several polyatomic ions are listed in **Table 5.** To name a compound that contains one of these ions, first write the name of the positive ion. Use **Table 5** to find the name of a polyatomic ion. Then write the name of the negative ion. For example,  $K_2SO_4$  is potassium sulfate. What is the name of  $Sr(OH)_2$ ? Begin by writing the name of the positive ion, strontium. Then find the name of the polyatomic ion,  $OH^-$ , which is hydroxide. Thus, the name is strontium hydroxide.

Table 5 Polyatomic Ions			
Charge	Name	Formula	
1+	ammonium	NH <sub>4</sub> <sup>+</sup>	
1-	acetate chlorate hydroxide nitrate	C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> <sup>-</sup> CIO <sub>3</sub> <sup>-</sup> OH <sup>-</sup> NO <sub>3</sub> <sup>-</sup>	
2-	carbonate sulfate	CO <sub>3</sub> <sup>2-</sup> SO <sub>4</sub> <sup>2-</sup>	
3—	phosphate	P0 <sub>4</sub> <sup>3-</sup>	

Writing Formulas To write formulas for these compounds, follow the rules for binary compounds, with one addition. When more than one polyatomic ion is needed, write parentheses around the polyatomic ion before adding the subscript. How would you write the formula of barium chlorate?

First, identify the symbol of the positive ion. Barium has the symbol Ba and forms a 2+ ion,  $Ba^{2+}$ . Next, identify the negative chlorate ion. **Table 5** shows that it is  $ClO_3^{-}$ . Finally, you need to balance the charges of the ions to make the compound neutral. It will take two chlorate ions with a 1- charge to balance the 2+ charge of the barium ion. Because the chlorate ion is polyatomic, you use parentheses before adding the subscript. The formula is  $Ba(ClO_3)_2$ . Another example of naming complex compounds is shown in **Figure 21**.

#### Figure 21 Naming Complex Compounds

How would a scientist write the chemical formula for ammonium phospate?

To write the formula, answer the following questions:

- 1. What is the positive ion and its charge? The positive ion is  $NH_4^{1+}$  and its charge is  $1^+$ .
- **2.** What is the negative ion and its charge? The negative ion is  $PO_4^{3-}$  and its charge is 3—.
- 3. Balance the charges to make the compound neutral. a) three  $NH_4^{1+}$  ions (+3) balance one  $PO_4^{3-}$  (3—)
  - b) The charge of one ion (without the sign) becomes the subscript of the other. Add parentheses for subscripts greater than 1. NH<sub>4</sub><sup>1+</sup> PO<sub>4</sub><sup>3-</sup> gives (NH<sub>4</sub>)<sub>3</sub>PO<sub>4</sub>

The chemical formula for ammonium phosphate is  $(NH_4)_3PO_4$ .



#### **Making a Hydrate**

#### **Procedure**

#### 

- 1. Complete the safety form.
- 2. Mix 150 g of plaster of paris with 75 mL of water in a small bowl.
- 3. Let the plaster dry overnight and then take the hardened plaster out of the bowl.
- 4. Lightly tap the plaster with a rubber hammer.
- 5. Heat the plaster with a hair dryer on the hottest setting and observe.
- **6.** Place a towel over the sample, then lightly tap the plaster with the hammer after heating it.

#### **Analysis**

- 1. What happened to the plaster when you tapped it before and after heating it?
- 2. What did you observe happening to the plaster as you heated it? Explain.

#### **Compounds with Added Water**

Some ionic compounds have water molecules as part of their structure. These compounds are called hydrates. A hydrate is a compound that has water chemically attached to its ions and written into its chemical formula.

**Common Hydrates** The term *hydrate* comes from a word that means "water." When a solution of cobalt chloride evaporates, pink crystals that contain six water molecules for each unit of cobalt chloride are formed. The formula for this compound is CoCl<sub>2</sub> • 6H<sub>2</sub>O and is called cobalt chloride hexahydrate.

You can remove water from these crystals by heating them. The resulting blue compound is called anhydrous, which means "without water." When anhydrous (blue) CoCl2 is exposed to water, even from the air, it will revert back to its hydrated state.

The plaster of paris shown in **Figure 22** also forms a hydrate when water is added. It becomes calcium sulfate dihydrate, which is also known as gypsum. The water that was added to the powder became a part of the compound.

To write the formula for a hydrate, write the formula for the compound and then place a dot followed by the number of water molecules. The dot in the formula represents a ratio of a compound to water molecules. For example, calcium sulfate dihydrate,  $CaSO_4 \cdot 2H_2O$ , is the formula for the hydrate of calcium sulfate that contains two molecules of water.

#### **Naming Binary Covalent Compounds**

Covalent compounds are those formed between elements that are nonmetals. Some pairs of nonmetals can form more than one compound with each other. For example, nitrogen and oxygen can form N<sub>2</sub>O, NO, NO<sub>2</sub> and N<sub>2</sub>O<sub>5</sub>. In the system you have learned so far, each of these compounds would be called nitrogen oxide. You would not know from that name what the composition of the compound is.

**Figure 22** The presence of water changes this powder into a material that can be used to create art.

**Identify** the formula for this powder prior to the addition of water.



**Using Prefixes** Scientists use the Greek prefixes in **Table 6** to indicate how many atoms of each element are in a binary covalent compound. The nitrogen and oxygen compounds  $N_2O_5$ , NO,  $NO_2$ , and  $N_2O_5$  would be named dinitrogen oxide, nitrogen oxide, nitrogen dioxide, and dinitrogen pentoxide. Notice that the last vowel of the prefix is dropped when the second element begins with a vowel, as in pentoxide. Often, the prefix *mono*- is omitted, although it is used for emphasis in some cases. Carbon monoxide is one example.



What prefix would be used for seven atoms of one element in a covalent compound?

These same prefixes are used when naming the hydrates previously discussed. The main ionic compound is named the regular way, but the number of water molecules in the hydrate is indicated by the Greek prefix.

You have learned how to write formulas of binary ionic compounds and of compounds containing polyatomic ions. Using oxidation numbers to write formulas, you can predict the ratio in which atoms of elements might combine to form compounds. You also have seen how hydrates have water molecules as part of their structures and formulas. Finally, you have learned how to use prefixes in naming binary covalent compounds. As you continue to study, you will see many uses of formulas.

Table 6 Prefixes for Covalent Compounds		
Number of Atoms	Prefix	
1	mono-	
2	di-	
3	tri-	
4	tetra-	
5	penta-	
6	hexa-	
7	hepta-	
8	octa-	

#### section

## 3

#### review

#### Summary

#### **Binary Ionic Compounds**

- A binary compound is one composed of two elements.
- The oxidation number tells how many electrons an atom has gained, lost, or shared to become stable.
- The net charge of a compound is zero.

#### **Compounds with Complex Ions**

- A polyatomic ion is a positively or negatively charged, covalently bonded group of atoms.
- A hydrate is a compound that has water chemically attached to its ions.
- Greek prefixes are used to indicate how many atoms of each element are in a binary covalent compound.

#### **Self Check**

- Use Formulas Write formulas for the following compounds: potassium iodide, magnesium hydroxide, aluminum sulfate, and chlorine heptoxide.
- **2. Use Formulas** Write the names of these compounds: KCl, Cr<sub>2</sub>O<sub>3</sub>, Ba(ClO<sub>3</sub>)<sub>2</sub>, NH<sub>4</sub>Cl, and PCl<sub>3</sub>.
- Name Mg<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub> 4H<sub>2</sub>O and write the formula for calcium nitrate trihydrate.
- Think Critically Explain why sodium and potassium will or will not react to form a bond with each other.

#### **Applying Math**

5. Solve One-Step Equations The overall charge on the polyatomic sulfate ion, found in some acids, is 2<sup>-</sup>. Its formula is SO<sub>4</sub><sup>2-</sup>. If the oxygen ion has a 2<sup>-</sup> oxidation number, determine the oxidation number of sulfur in this polyatomic ion.



#### **Model and Invent**

## Modeling Chemical Bonding

#### Goals

- Infer chemical formulas by making models of outer electron levels.
- Compare and contrast models of ionic and covalent bonding.
- Draw and label diagrams to illustrate chemical bonding.

#### **Possible Materials**

modified egg carton beans

- \*pennies
- \*buttons
- \*Alternate materials

#### **Safety Precautions**



#### Real-World Problem

Chemical bonding is one of the most important concepts in chemistry. Bonding is what makes different compounds. Even though atoms have a nucleus containing protons and neutrons, the part of the atom that is most important to chemists is outside the nucleus. How are electrons involved in chemical bonding?

#### 🧶 Make a Model=

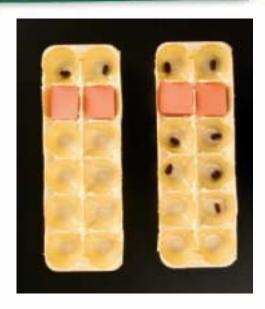
- 1. Complete the safety form before you begin.
- 2. Obtain a modified egg carton and beans from your teacher. The egg carton represents the first and second energy levels of an atom. The beans represent electrons.
- **3. Decide** which elements you can model by the number of beans you have. Consider how the periodic table can be used to determine the number of outer electrons in an element.
- **4. Model** all the elements that you can create using the modified egg carton and beans.
- 5. Draw the models of elements that you created in your Science Journal.
- **6. Determine** if the elements form ionic or covalent bonding. Record your conclusions in your Science Journal.



### Using Scientific Methods

#### Test Your Model

- Look for element combinations that could represent chemical formulas for compounds and molecules. Some formulas may require more than one atom to form some types of elements and compounds.
- **2.** Work with other students to make models of compounds and molecules produced by chemical bonding.
- Draw the models of the compounds and molecules you made in your Science Journal. Record the type of bonding used to make the compounds and molecules.



#### 🧶 Analyze Your Data

- **1. Explain** how you can use the periodic table to identify the element that represents your model.
- **2. Explain** whether elements in the metal groups on the periodic table have more or fewer electrons in their outer energy levels than the nonmetals.
- **3.** The combinations of elements could represent chemical formulas. Explain why some formulas require more than one atom of an element.

#### Conclude and Apply

- 1. **Describe** why your model could be used to show examples of both ionic and covalent bonding.
- 2. **Predict** what element your model would be if you received ten beans. Explain your reasoning.



**Compare** your conclusions with other students' conclusions. What elements did their models represent? Explain how their elements differed in ability to form ionic and covalent bonds.

# Accidents in SCIENCE

SOMETIMES
GREAT
DISCOVERIES
HAPPEN BY
ACCIDENT!

# ASticky Subject



n 1942, a research team was working on creating a new kind of glass. The group was working with some cyanoacrylate monomers (si uh noh A kruh layt • MAH nuh muhrz) that showed promise, but a problem kept coming up. Everything the monomers touched stuck to everything else!

Cyanoacrylate is the chemical name for instant, supertype glues. The researchers were so focused on finding a different type of glass that at the time, none of them recognized that they were working with an important new adhesive.

In 1952, a member of the research team, working on new materials for jet plane canopies, made a similar complaint. The ethyl cyanoacrylate the team was working with again made everything stick together. This time, the insight stuck to the scientists like, well, like GLUE! "I began gluing everything I could lay my hands on—glass plates, rubber stoppers,

metal spatulas, wood, paper, plastic. Everything stuck to everything, almost instantly, and with bonds I could not break apart," recalls the head of the research group.

#### Stick to It

Most adhesives, commonly called glues, are long chains of bonded molecules called polymers. Cyanoacrylate, however, exists as monomers—single molecules with double bonds. And it stays that way until it hits anything with moisture in it, such as air. Yes, even the small amount of moisture in air and on the surfaces of most materials is enough to dissolve the double bonds in the monomers of cyanoacrylate, making them join together in long chains. The chains bond to surfaces as they polymerize.

The discovery of cyanoacrylates had an immediate impact on the automobile and airplane industries. And it soon "held" a spot in almost every household toolbox. Since the 1990s, cyanoacrylate glues have also found a place in doctors' offices. A doctor can apply a thin layer of instant glue instead of putting stitches in a cut. This specially made medical glue was approved by the U.S. Food and Drug Administration in 1998.



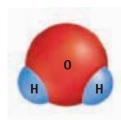
**Take Note** Visit a store and make a table of different kinds of glues. List their common names, their chemical names, what they are made of, how long it takes them to set, and the types of surfaces for which they are recommended. Note any safety precautions.



#### Reviewing Main Ideas

#### **Section 1 Stability in Bonding**

- **1.** The properties of compounds are generally different from the properties of the elements they contain.
- **2.** A chemical formula for a compound indicates the composition of a unit of the compound. This model of a water molecule shows the shape of the molecule and the relative sizes of the atoms.



**3.** Chemical bonding occurs because atoms of most elements become more stable by gaining, losing, or sharing electrons to obtain stable outer energy levels.

#### **Section 2** Types of Bonds

**1.** Covalent bonds are formed by the sharing of electrons. Ionic bonds between atoms are formed by the attraction between ions. Below is an example of an ionically bonded compound.



2. Ionic bonding occurs between charged particles called ions and produces ionic compounds. Covalent bonding produces units called molecules and occurs between nonmetallic elements.

**3.** The unequal sharing of electrons produces compounds that contain polar bonds, and the equal sharing of electrons produces nonpolar compounds.

#### Section 3

#### **Writing Formulas and Naming Compounds**

- **1.** An oxidation number indicates how many electrons an atom has gained, lost, or shared when bonding with other atoms.
- 2. In the formula of an ionic compound, the element or ion with the positive oxidation number is written first, followed by the one with the negative oxidation number.
- **3.** The name of a binary compound is derived from the names of the two elements that compose the compound. Salt is an example of a binary compound, sodium chloride.



- **4.** A hydrate is a compound that has water chemically attached to its ions and written into its formula.
- **5.** Greek prefixes are used in the names of covalent compounds. These indicate the number of each atom present.

FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review chemical bonds.

#### **Using Vocabulary**

binary compound p. 703 chemical bond p. 694 chemical formula p. 689 covalent bond p. 697 hydrate p. 708 ion p. 692 ionic bond p. 696 molecule p. 697 nonpolar molecule p. 700 oxidation number p. 703 polar molecule p. 700 polyatomic ion p. 707

Match each phrase with the correct vocabulary word or phrase.

- 1. a charged group of atoms
- **2.** a compound composed of two elements
- 3. a molecule with partially charged areas
- **4.** a positively or negatively charged particle
- **5.** a chemical bond between oppositely charged ions
- **6.** a bond formed from shared electrons
- **7.** a crystalline substance that contains water
- **8.** a particle made of covalently bonded atoms
- 9. shows an element's combining ability
- **10.** tells which elements are in a compound and their ratios.

#### **Checking Concepts**

Choose the word or phrase that best answers the question.

- **11.** Which elements are least likely to react with other elements?
  - A) metals
- **c)** nonmetals
- **B)** noble gases
- **D)** transition elements
- **12.** What is the name of CuO?
  - **A)** copper oxide
    - **B)** copper(I) oxide
    - **C)** copper(II) oxide
    - **D)** copper(III) oxide

- **13.** Which formula represents a nonpolar molecule?
  - A)  $N_2$
- c) NaCl
- **B)**  $H_{2}^{-}O$
- D) HCl
- **14.** How many electrons are in the outer energy levels of Group 17 elements?
  - **A)** 1

**c)** 7

**B)** 2

- **D)** 17
- **15.** Which is a binary ionic compound?
  - A)  $O_2$
- C)  $H_2SO_4$
- B) NaF
- **D)**  $Cu(NO_3)_2$
- **16.** Which is an anhydrous compound?
  - A)  $H_2O$
- **c)**  $CuSO_4 \cdot 5H_2O$
- **B)**  $\overline{\text{CaSO}_4}$
- **D)** CaSO $_4 \cdot 2H_2^2$ O
- 17. Which atom has gained an electron?
  - **A)** negative ion
  - **B)** positive ion
  - **C)** polar molecule
  - **D)** nonpolar molecule
- **18.** Which is a covalent compound?
  - A) sodium chloride
  - **B)** calcium fluoride
  - **c)** calcium chloride
  - **D)** sulfur dioxide

#### Interpreting Graphics

**19.** Copy and complete the concept map.

**20. Identify** and write the name and formula for the compound illustrated to the right.



Use the table below to answer question 21.

Which compounds exist?		
Formula	Possible Compounds	
SF <sub>6</sub>	AIF <sub>6</sub> or TeF <sub>6</sub>	
K <sub>2</sub> SO <sub>4</sub>	Na <sub>2</sub> SO <sub>4</sub> or Ba <sub>2</sub> SO <sub>4</sub>	
CO <sub>2</sub>	CCI <sub>2</sub> or CS <sub>2</sub>	
CaCO <sub>3</sub>	OCO <sub>3</sub> or BaCO <sub>3</sub>	

21. Predict Elements from one family (vertical column) of the periodic table generally combine with elements from another family and polyatomic ions in the same ratio. For example, one calcium atom combines with two chlorine atoms to give CaCl<sub>2</sub> (calcium chloride), as it does with two fluorine atoms to give CaF<sub>2</sub> (calcium fluoride). Using the periodic table as a guide, predict which of the two compounds on the right side of the table above is more likely to exist based upon the formula on the left side.

#### **Thinking Critically**

- **22. Draw** Anhydrous magnesium chloride is used to make wood fireproof. Draw a dot diagram of magnesium chloride.
- **23. Use Formulas** Artificial diamonds are made using thallium carbonate. If thallium has an oxidation number of 1+, what is the formula for the compound?
- **24. Compare and contrast** polar and nonpolar molecules.

- **25. Write** Baking soda, which is sodium hydrogen carbonate, and vinegar, which contains hydrogen acetate, can be used as household cleaners. Write the chemical formulas for these two compounds.
- **26. Draw Conclusions** Ammonia gas and water react to form household ammonia, which contains NH<sub>4</sub><sup>+</sup> and OH<sup>-</sup> ions. The formula for water is H<sub>2</sub>O. What is the formula for ammonia gas?
- **27. Draw Conclusions** The name of a compound called copper(II) sulfate is written on a bottle. What is the charge of the copper ion? What is the charge of the sulfate ion?
- **28. Explain** what electric forces between oppositely charged electrons and protons have to do with chemical reactions.
- **29.** Name Compounds Write the chemical name for the following compounds.
  - A)  $Fe_2S_3$
- C)  $Ca(PO_4)_2$
- **B)**  $Cu(ClO_3)_2$
- **D)**  $(NH_4)_2SO_4$
- **30. Model** One common form of phosphorus, white phosphorus, has the formula P<sub>4</sub> and is formed by four covalently bonded phosphorus atoms. Make a model of this molecule, showing that all four atoms are now chemically stable.
- **31. Determine** the chemical formulas for the following compounds.
  - **A)** potassium chloride
  - **B)** calcium carbonate
  - **c)** copper sulfate
  - **D)** sodium oxide

#### **Applying Math**

- **32.** Use Numbers What is the oxidation number of Fe in the compound  $Fe_2S_3$ ?
  - **A)** 1 <sup>+</sup>
- **C)** 3<sup>+</sup>
- **B)** 2<sup>+</sup>
- **D)** 4<sup>+</sup>

#### Standardized Test Practice chapter

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### **Multiple Choice**

- 1. Which statement about this molecule is TRUE?
  - **A.** This is a nonpolar molecule.
  - **B.** The electrons are shared equally in the bonds of this molecule.
  - **c.** This molecule does not have oppositely charged ends.
  - **D.** This is a polar molecule.

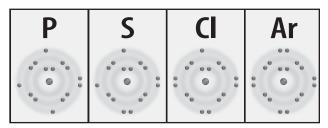
#### Use the figure below to answer question 2.



- 2. What type of bond holds the atoms of this molecule together?
  - A. covalent
  - B. ionic
  - **c.** triple
  - **D.** double
- **3.** What do the Group 7A elements become when they react with Group 1A elements?
  - **A.** negative ions
  - **B.** neutral
  - **C.** positive ions
  - **D.** polyatomic ions

- **4.** What is the name of  $KC_2H_3O_2$ ?
  - **A.** potassium carbide
  - **B.** potassium acetate
  - **C.** potassium hydroxide
  - **D.** potassium oxide
- **5.** What is the chemical formula for lead(ll) oxide?
  - A. PbO
  - B. Pb<sub>2</sub>O
  - **c.** PbO<sub>2</sub>
  - **D.** Pb<sub>2</sub>O<sub>2</sub>

Use the illustration below to answer question 6.



- **6.** How many electrons are required to complete the outer energy level of a phosphorous atom?
  - A. one
  - B. two
  - **C.** three
  - D. four

#### **Test-Taking Tip**

**Comprehension** Be sure you understand the question before you read the answer choices. Make special note of words like NOT or EXCEPT. Read and consider all the answer choices before you mark your answer sheet.

- 7. Which element is **NOT** part of the compound NH<sub>4</sub>NO<sub>3</sub>?
  - A. nitrogen
  - **B.** nickel
  - **C.** oxygen
  - **D.** hydrogen

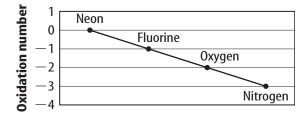
#### Gridded Response

- **8.** When an atom is chemically stable, how many electrons are in its outer energy level?
- **9.** How many electrons are there in an argon atom?

#### Short Response

Use the illustration below to answer question 10.

#### **Oxidation Numbers of Some Period 2 Elements**



- **10.** Compare the oxidation numbers of nitrogen and fluorine. Why do they differ?
- 11. The bonding of atoms and molecules is the result of oppositely charged electrons and protons being held together by electric forces within the atoms. Using this information, explain the bonding of NaCl.

#### Extended Response

**12.** KCl is an example of ionic bonding. HCl is an example of covalent bonding. Describe the difference in the bonds in terms of electrons and outer energy levels.

Use the illustration below to answer question 13.

- **13.** Describe the bond holding the nitrogen atoms together in this molecule.
- **14.** Nitrogen occurs naturally as a diatomic molecule because N<sub>2</sub> molecules are more stable than nitrogen atoms.  $H_2$ ,  $O_2$ ,  $F_2$ , Cl<sub>2</sub>, Br<sub>2</sub>, and I<sub>2</sub> are other diatomic molecules. Draw dot diagrams for three of these molecules.
- **15.** Explain why elements in Groups 4A, which have four electrons in their outer energy levels, are unlikely to lose all of the electrons in their outer energy levels.
- **16.** What factors affect how strongly an atom is attracted to its electrons?
- **17.** Create a chart that compares the properties of polar and nonpolar molecules. Your chart should include several examples of each type of molecule.
- **18.** What is the difference between nitrogen oxide and dinitrogen pentoxide? Why are prefixes used to name these compounds?

#### chapter

23

#### BIG (Idea

A chemical reaction involves changing one or more substances into a different substance or substances.

#### 23.1 Chemical Changes

MAIN (Idea The rearrangement of atoms in a chemical change is described by a chemical equation.

#### 23.2 Chemical Equations

MAIN (Idea A balanced chemical equation contains the same numbers and types of atoms in the reactants as in the products.

### 23.3 Classifying Chemical Reactions

**MAIN** (Idea Reactions can be classified based on how atoms are rearranged.

### 23.4 Reaction Rates and Energy

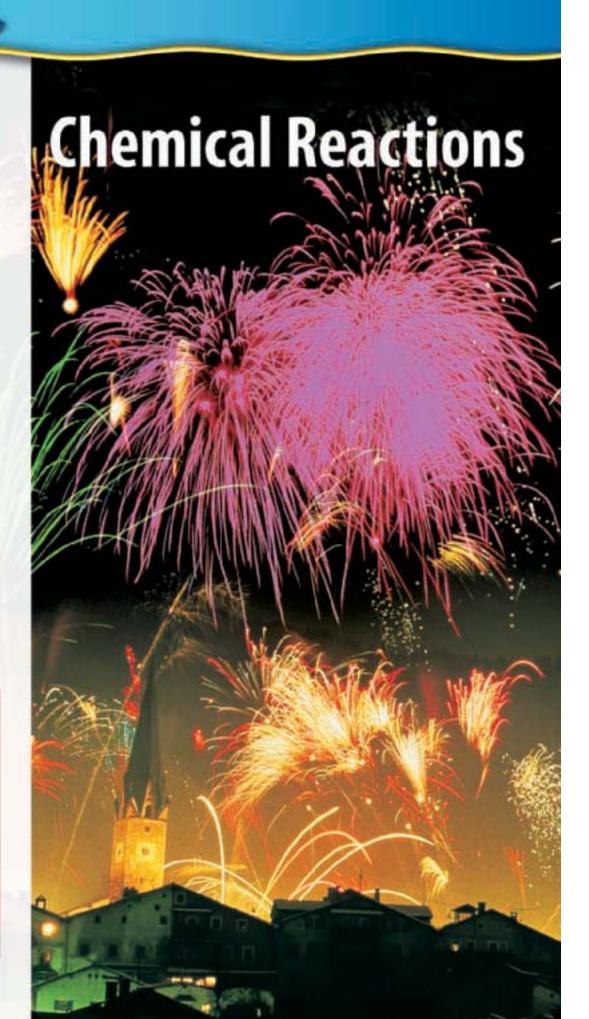
MAIN (Idea Exergonic reactions release energy and endergonic reactions absorb energy.

#### All-American Chemistry

Few things are as American as fireworks on the Fourth of July. Crowds everywhere enjoy the explosions of color and deafening booms. These sights and sounds are the results of chemical reactions.

#### **Science Journal**

Describe several events that might happen in your refrigerator. Later, decide which of the events are chemical reactions.



#### **Start-Up Activities**



#### **Rusting—A Chemical Reaction**

Like exploding fireworks, rusting is a chemical reaction in which iron metal combines with oxygen. Other metals combine with oxygen, too—some more readily than others. In this lab, you will compare how iron and aluminum react with oxygen.



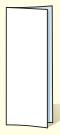
- 1. Complete the safety form.
- 2. Place a clean iron or steel nail in a dish prepared by your teacher.
- 3. Place a clean aluminum nail in a second dish. These dishes contain agar gel and an indicator that detects a reaction with oxygen.
- 4. Observe both nails after one hour. Record any changes around the nails in your Science Journal.
- **5.** Carefully examine both of the dishes the next day.
- **6. Think Critically** Record any differences you noticed between the two dishes. Predict if a reaction occurred. How can you tell? What might have caused the differences you observed between the two nails. Explain.



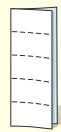
**Chemical Reactions** Make the following Foldable to help you classify chemical reactions.

STEP 1

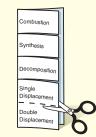
Fold a sheet of paper in half lengthwise.



Mark four lines evenly spaced at even intervals down the page.



Cut only the top layer along the four marks to make five tabs. Label the tabs as shown.



**Classify** As you read, record examples of each type of reaction from the book, then review the chapter and list other examples mentioned in the text or from classroom discussions.



Preview this chapter's content and activities at gpescience.com

## **Chemical Changes**

#### **Reading Guide**

#### What You'll Learn

- Identify the reactants and products in a chemical reaction.
- Determine how a chemical reaction satisfies the law of conservation of mass.
- **Determine** how chemists express chemical changes using equations.

#### Why It's Important

Chemical reactions cook our food, warm our homes, and provide energy for our bodies.

#### Review Vocabulary

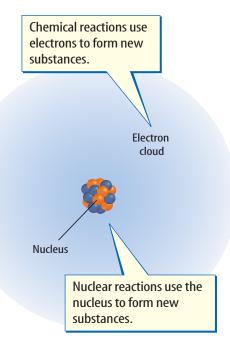
chemical change: change of one substance into a new substance

#### New Vocabulary

- chemical reaction
- reactant
- product
- chemical equation

**Figure 1** Different parts of the atom are used in chemical and nuclear reactions.

**Identify** how chemical bonds are formed.



#### **Describing Chemical Reactions**

Dark mysterious mixtures react, gas bubbles up and expands, and powerful aromas waft through the air. Where are you? You are in the kitchen baking a chocolate cake. Nowhere in the house do so many chemical reactions take place as in the kitchen.

Chemical reactions are taking place all around you and even within you. A chemical reaction is a change in which one or more substances are converted into new substances. The substances that react are called **reactants**. The new substances produced are called **products**.

**Chemical and Nuclear Reactions** When chemical reactions occur, new compounds form when bonds between atoms in the reactants break and new bonds form. Recall that chemical bonds form when outer electrons, called valence electrons, are shared between atoms or are transferred from one atom to another. As a result, only the outer electrons of atoms are involved in chemical reactions. The nucleus of an atom is not affected by a chemical reaction. An atomic nucleus changes only when nuclear decay or a nuclear reaction, such as nuclear fission or fusion, occurs. The energy released by a nuclear reaction is millions of times greater than the energy released by a chemical reaction. Figure 1 summarizes the difference between nuclear and chemical reactions.

#### **Conservation of Mass**

By the 1770s, chemistry was changing from the art of alchemy to a true science. Instead of being satisfied with a superficial explanation of unknown events, scientists began to study chemical reactions more thoroughly. Through such study, the French chemist Antoine Lavoisier established that the total mass of the products always equals the total mass of the reactants. This principle is illustrated in **Figure 2**.

The Father of Modern Chemistry When Lavoisier demonstrated the law of conservation of mass, he set the field of chemistry on its modern path. In fact, Lavoisier is known today as the father of modern chemistry for his more accurate explanation of the conservation of mass and for describing a common type of chemical reaction called combustion, which you will learn about later in this chapter. Lavoisier also pioneered early experimentation on the biological phenomena of respiration and metabolism that contributed early milestones in the study of biochemistry, medicine, and even sports medicine.



How did Lavoisier's contributions earn him the title of Father of Modern Chemistry?

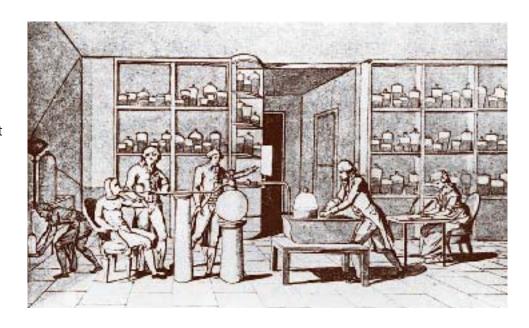
**Nomenclature** Antoine Lavoisier's work led him to the conclusion that language terminology would be critical to communicate novel scientific ideas. Lavoisier began to develop the system of naming substances based on their composition that we still use today. In 1787, Lavoisier and several colleagues published Méthode de Nomenclature Chimique as one of the first sets of nomenclature guidelines.



**Figure 2** The mass of the candles and oxygen before burning is exactly equal to the mass of the remaining candle and gaseous products.

**Describe** the principle that is represented in this figure.

Figure 3 Antoine Lavoisier's wife, Marie-Anne, drew this view of Lavoisier in his laboratory performing studies on oxygen. She depicted herself at the right taking notes.





#### **Topic: Antoine Lavoisier**

Visit **gpescience.com** for Web links to information about Antoine Lavoisier and his contributions to chemistry.

**Activity** In your Science Journal, write a brief biography of Antoine Lavoisier that includes some of his non-scientific activities and political interests, as well as his scientific contributions.

**Lavoisier's Contribution** One of the questions that motivated Lavoisier was the mystery of exactly what happened when substances changed form. He began to answer this question by experimenting with mercury. In one experiment, Lavoisier placed a carefully measured mass of solid mercury(II) oxide, which he knew as mercury calx, into a sealed container. When he heated this container, he noted a dramatic change. The red powder had been transformed into a silvery liquid that he recognized as mercury metal, and a gas was produced. When he determined the mass of the liquid mercury and gas, their combined masses were exactly the same as the mass of the red powder he had started with.

mercury(II) oxide oxygen plus mercury  

$$10.0 \text{ g}$$
 =  $0.7 \text{ g}$  +  $9.3 \text{ g}$ 

Lavoisier also established that the gas produced by heating mercury(II) oxide, which we call oxygen, was a component of air. He did this by heating mercury metal with air and saw that a portion of the air combined to give red mercury(II) oxide. He studied the effect of this gas on living animals, including himself. Hundreds of experiments carried out in his laboratory, as shown in **Figure 3**, confirmed that in a chemical reaction, matter is not created or destroyed, but is conserved. This principle became known as the law of conservation of mass. This means that the total starting mass of all reactants equals the total final mass of all products.



**Reading Checks** What does the law of conservation of mass state?

#### **Writing Equations**

If you wanted to describe the chemical reaction shown in **Figure 4**, you might write something like this:

Nickel(II) chloride, dissolved in water, plus sodium hydroxide, dissolved in water, produces solid nickel(II) hydroxide plus sodium chloride, dissolved in water.

This series of words is rather cumbersome, but all of the information is important. The same is true of descriptions of most chemical reactions. Many words are needed to state all the important information. As a result, scientists have developed a shorthand method to describe chemical reactions. A **chemical equation** is a way to describe a chemical reaction using chemical formulas and other symbols. Some of the symbols used in chemical equations are listed in Table 1.

The chemical equation for the reaction described above in words and shown in **Figure 4** looks like this:

$$\text{NiCl}_2(aq) + 2\text{NaOH}(aq) \longrightarrow \text{Ni(OH)}_2(s) + 2\text{NaCl}(aq)$$

On the left side of the equation are the reactants, nickel(II) chloride and sodium hydroxide. On the right side of the equation are the products, nickel(II) hydroxide and sodium chloride.

It is much easier to tell what is happening by writing the information in this form. Later, you will learn how chemical equations make it easier to calculate the quantities of reactants that are needed and the quantities of products that are formed.

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**Figure 4** A white precipitate of nickel(II) hydroxide forms when sodium hydroxide is added to a green solution of nickel(II) chloride. Sodium chloride, the other product formed, is in solution.

Table 1 Symbols Used in Chemical Equations			
Symbol	Meaning		
$\rightarrow$	produces or yields		
+	plus		
(s)	solid		
<i>(I)</i>	liquid		
(g)	gas		
(aq)	aqueous, a substance is dissolved in water		
$\overset{\text{heat}}{\rightarrow}$	the reactants are heated		
$\stackrel{light}{\to}$	the reactants are exposed to light		
elec. →	an electric current is applied to the reactants		



### **Designing a Team Equation**

#### **Procedure**

- Obtain 15 index cards and mark each as follows: five with Guard, five with Forward, and five with Center.
- 2. Group the cards to form as many complete basketball teams as possible. Each team needs two guards, two forwards, and one center.

#### **Analysis**

- Write the formula for a team. Write the formation of a team as an equation. Use coefficients in front of each type of player needed for a team.
- 2. How is this equation like a chemical equation? Why can't you use the remaining cards?
- 3. How do the remaining cards illustrate the law of conservation of matter in this example?

#### **Unit Managers**

What do the numbers to the left of the formulas for reactants and products mean? Remember that according to the law of conservation of mass, matter is neither made nor lost during chemical reactions. Atoms are rearranged but never lost or destroyed. These numbers, called coefficients, represent the number of units of each substance taking part in a reaction. Coefficients can be thought of as unit managers.



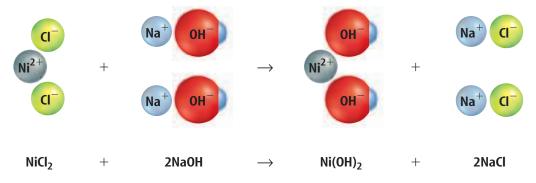
What is the function of coefficients in a chemical equation?

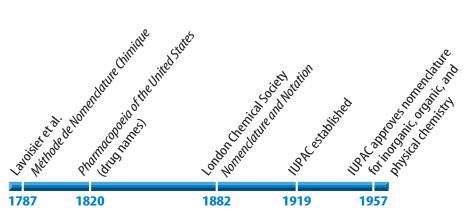
Imagine that you are responsible for making sand-wiches for a picnic. You have been told to make a certain number of three kinds of sandwiches, and that no substitutions can be made. You would have to figure out exactly how much food to buy so that you had enough without any food left over. You might need two loaves of bread, four packages of turkey, four packages of cheese, two heads of lettuce, and ten tomatoes. With these supplies you could make exactly the right number of each kind of sandwich.

In a way, your sandwich-making effort is like a chemical reaction. The reactants are your bread, turkey, cheese, lettuce, and tomatoes. The number of units of each ingredient are similar to the coefficients of the reactants in an equation. The sandwiches are similar to the products, and the numbers of each kind of sandwich are similar to the coefficients.

Knowing the number of units of reactants enables chemists to add the correct amounts of reactants to a reaction. Also, these units, or coefficients, tell them exactly how much product will form. An example of this is the reaction of one unit of NiCl<sub>2</sub> with two units of NaOH to produce one unit of Ni(OH)<sub>2</sub> and two units of NaCl. You can see these units in **Figure 5.** 

**Figure 5** Each coefficient in the equation represents the number of units of each type in this reaction.





**IUPAC** Antoine Lavoisier and his colleagues understood the importance of using a nomenclature system that helps scientists communicate their data. Since that time, the guidelines have continued to evolve with scientific discovery. In 1919, the International Union of Applied Chemistry (IUPAC) was formed. The primary mission of the IUPAC is to coordinate guidelines for naming chemical compounds systematically. Figure 6 illustrates some of the early events in nomenclature development.

In addition to chemical nomenclature, IUPAC also is responsible for standardizing chemistry methods, evaluating atomic weights and environmental programs, along with many other areas relating to chemistry.

**Figure 6** This time line of nomenclature development and publications does not end in 1957. In fact, today there are nomenclature organizations for almost every branch of scientific study, and the rules and guidelines for naming substances continue to evolve.

#### section

#### review

#### **Summary**

#### **Describing Chemical Reactions**

- A chemical reaction is a process that involves one or more reactants changing into one or more products.
- In chemical reactions and nuclear reactions, different parts of the atom form new substances.

#### **Conservation of Mass**

 A basic principle of chemistry is that matter, during a chemical change, can neither be created nor destroyed.

#### **Writing Equations**

• Chemical equations describe the change of reactants to products and obey the law of conservation of mass.

#### **Unit Managers**

• Coefficients represent how many units of each substance are involved in a chemical reaction.

#### **Self Check**

1. Identify the reactants and the products in the following chemical equation.

$$Cd(NO_3)_2(aq) + H_2S(g) \longrightarrow CdS(s) + 2HNO_3(aq)$$

2. Identify the state of matter of each substance in the following reaction.

$$Zn(s) + 2HCI(aq) \longrightarrow H_2(g) + ZnCI_2(aq)$$

- 3. Compare and contrast a chemical reaction and a nuclear reaction.
- **4. Explain** the importance of the law of conservation of mass.
- 5. Think Critically How would global communication between scientists have been changed if IUPAC had not been established?

#### **Applying Math**

6. Solve One-Step Equations When making soap, if 890 g of a specific fat react completely with 120 g of sodium hydroxide, the products formed are soap and 92 g of glycerin. Calculate the mass of soap formed to satisfy the law of conservation of mass.

## **Chemical Equations**

#### **Reading Guide**

#### What You'll Learn

- Identify what is meant by a balanced chemical equation.
- Determine how to write balanced chemical equations.

#### Why It's Important

Chemical equations are the language used to describe chemical change, which allow scientists to develop products for our world.

#### Review Vocabulary

subscript: in a chemical formula, a number below and to the right of a symbol indicating number of atoms

#### **New Vocabulary**

• balanced chemical equation

#### **Balanced Equations**

Lavoisier's mercury(II) oxide reaction, shown in **Figure 7**, can be written as:

$$\mathsf{HgO}(s) \xrightarrow{\mathsf{heat}} \mathsf{Hg}(l) + \mathsf{O}_2(g)$$

Notice that the number of mercury atoms is the same on both sides of the equation but that the number of oxygen atoms is not the same. One oxygen atom appears on the reactant side of the equation and two appear on the product side.

But according to the law of conservation of mass, one oxygen atom cannot just become two. Nor can you simply add the subscript 2 and write HgO<sub>2</sub> instead of HgO. The formulas HgO<sub>2</sub> and HgO do not represent the same compound. In fact, HgO2 does not exist. The formulas in a chemical equation must accurately represent the compounds that react.

Fixing this equation requires a process called balancing. Balancing an equation doesn't change what happens in a reaction—it simply changes the way the reaction is represented. The balancing process involves changing coefficients in a reaction to achieve a balanced chemical equation, which has the same number of atoms of each element on both sides of the equation.

**Figure 7** Mercury metal forms when mercury oxide is heated. Because mercury is poisonous, this reaction is never performed in a classroom laboratory.



**Choosing Coefficients** Finding out which coefficients to use to balance an equation is often a trial-and-error process. In the equation for Lavoisier's experiment, the number of mercury atoms is balanced, but one oxygen atom is on the left and two are on the right. If you put a coefficient of 2 before the HgO on the left, the oxygen atoms will be balanced, but the mercury atoms become unbalanced. To balance the equation, also put a 2 in front of mercury on the right. The equation is now balanced.

Balancing Equations Magnesium burns with such a brilliant white light that it is often used in emergency flares as shown in Figure 8. Burning leaves a white powder called magnesium oxide. To write a balanced chemical equation for this and most other reactions, follow these four steps.

**Step 1** Write a chemical equation for the reaction using formulas and symbols. Recall that oxygen is a diatomic molecule.

$$Mg(s) + O_2(g) \rightarrow MgO(s)$$

**Step 2** Count the atoms in reactants and products.

Atoms	Mg	+	$O_2$	$\rightarrow$	MgO
Mg	1				1
O			2		1

The magnesium atoms are balanced, but the oxygen atoms are not. Therefore, this equation isn't balanced.

**Step 3** Choose coefficients that balance the equation. Remember, never change subscripts of a correct formula to balance an equation. Try putting a coefficient of 2 before MgO.

$$Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

**Step 4** Recheck the numbers of each atom on each side of the equation and adjust coefficients again if necessary. Now two Mg atoms are on the right side and only one is on the left side. So a coefficient of 2 is needed for Mg to balance the equation.

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$



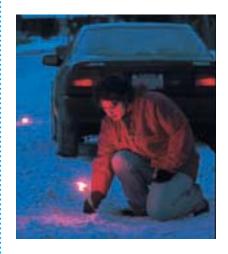
How can you balance a chemical equation using coefficients?



#### **Topic: Balancing Chemical Equations**

Visit gpescience.com for Web links to information about balancing chemical equations.

**Activity** Using the Web links, locate a website that offers practice problems for balancing chemical equations. Copy several of the unbalanced equations in your Science Journal and try to balance them. Check your work against the answers on the web site when you are done.



**Figure 8** Magnesium combines with oxygen, giving an intense white light.

#### **Applying Math**

#### **Use Coefficients**

**BARIUM SULFATE REACTION** A sample of barium sulfate is placed on a piece of paper, which is then ignited. Barium sulfate reacts with the carbon from the burned paper producing barium sulfide and carbon monoxide. Write a balanced chemical equation for this reaction.

#### **IDENTIFY** known values

We know the substances that are involved in the reaction. From this, we can write a chemical equation showing reactants and products.

$$BaSO_4(s) + C(s) \rightarrow BaS(s) + CO(g)$$

#### SOLVE the problem

The chemical equation above is not balanced. There are more oxygen atoms on the left side of the equation than there are on the right side. This must be corrected while keeping all other atom counts in balance. Begin to balance the equation by first counting and listing the atoms before and after the reaction.

Kind of Atom	Number of Atoms Before Reaction	Number of Atoms After Reaction
Ba	1	1
S	1	1
O	4	1
С	1	1

Next, adjust the coefficients until all atoms are balanced on the left and right sides of the arrow. Try putting a 4 in front of CO. Now you have 4 oxygen atoms on the right, which balances on both sides, but the carbon atoms become unbalanced. To fix this, add a 4 in front of the C in the reactants. The balanced equation looks like this:

$$BaSO_4(s) + 4C(s) \rightarrow BaS(s) + 4CO(g)$$

#### **CHECK** your answer

Count the number of atoms on each side of the equation and verify that they are equal.

#### **Practice Problems**

- **1.** Balance this equation: NaOH(aq) + CaBr<sub>2</sub>(aq)  $\rightarrow$  Ca(OH)<sub>2</sub>(s) + NaBr(aq).
- **2.** HCl is slowly added to aqueous Na<sub>2</sub>CO<sub>3</sub> forming NaCl, H<sub>2</sub>O, and CO<sub>2</sub>. Follow the steps above to write a balanced equation for this reaction.

For more practice problems, go to page 879, and visit Math Practice at <a href="mailto:gpescience.com">gpescience.com</a>.

**Polish Your Skill** When lithium metal is treated with water, hydrogen gas and lithium hydroxide are produced, as shown in Figure 9.

**Step 1** Write the chemical equation.

$$Li(s) + H_2O \rightarrow LiOH(aq) + H_2(g)$$

**Step 2** Check for balance by counting the atoms.

This equation is not balanced. There are three hydrogen atoms on the right and only two on the left. Complete steps 3 and 4 to balance the equation. After each step, count the atoms of each element. When equal numbers of atoms of each element are on both sides, the equation is balanced. The balanced chemical equation looks like this:

$$2\text{Li} + 2\text{H}_2\text{O} \rightarrow 2\text{LiOH} + \text{H}_2$$

The coefficients and subscripts are multiplied together, not added, to determine the correct number of atoms for each element.



Figure 9 When lithium metal is added to water, it reacts, producing a solution of lithium hydroxide and bubbles of hydrogen gas.

#### section гечіеш

#### **Summary**

#### **Balanced Equations**

- A chemical equation is a way to indicate reactants and products and relative amounts of each.
- A balanced chemical equation tells the exact number of atoms involved in the reaction.
- Balanced chemical equations must satisfy the law of conservation of matter; no atoms of reactant or product can be lost from one side to the other.
- Coefficients are used to achieve balance in a chemical equation.
- Chemical equations cannot be balanced by adjusting the subscript numerals in compound names because doing so would change the compounds.

#### **Self Check**

- 1. **Describe** two reasons for balancing chemical equations.
- **2.** Balance this chemical equation: Fe(s)  $+ 0_2(g) \longrightarrow \text{FeO}(s)$ .
- 3. Explain why oxygen gas must always be written as  $0_2$ in a chemical equation.
- **4. Infer** What coefficient is assumed if no coefficient is written before a formula in a chemical equation?
- 5. Think Critically Explain why the sum of the coefficients on the reactant side of a balanced equation does not have to equal the sum of the coefficients on the product side of the equation.

#### **Applying Math**

**6. Use Numbers** Balance the equation for the reaction  $Fe(s) + Cl_2(g) \longrightarrow FeCl_3(s)$ .

## 3

# Classifying Chemical Reactions

#### **Reading Guide**

#### What You'll Learn

- Identify the five general types of chemical reactions.
- Identify redox reactions.
- Predict which metals will replace other metals in compounds.

#### Why It's Important

Classifying chemical reactions helps to understand what is happening and predict the outcome of reactions.

#### Review Vocabulary

**states of matter:** the physical forms in which all matter naturally exists, most commonly solid, liquid, and gas

#### **New Vocabulary**

- combustion reaction
- synthesis reaction
- decomposition reaction
- single-displacement reaction
- double-displacement reaction

**Figure 10** Rust has accumulated on the *Titanic* since it sank in 1912. **Identify** the general formula for a synthesis reaction.



#### **Types of Reactions**

You might have noticed that there are all sorts of chemical reactions. In fact, there are literally millions of chemical reactions that occur every day, and scientists have described many of them and continue to describe more. With all these reactions, it would be impossible to use the information without first having some type of organization. With this in mind, chemists have defined five main categories of chemical reactions: combustion, synthesis, decomposition, single displacement, and double displacement.

**Combustion Reactions** If you have ever observed something burning, you have observed a combustion reaction. As mentioned previously, Lavoisier was one of the first scientists to accurately describe combustion. He deduced that the process of burning (combustion) involves the combination of a substance with oxygen. A **combustion reaction** occurs when a substance reacts with oxygen to produce energy in the form of heat and light. Combustion reactions also produce one or more products that contain the elements in the reactants. For example, the reaction between carbon and oxygen produces carbon dioxide. Many combustion reactions also will fit into other categories of reactions. For example, the reaction between carbon and oxygen also is a synthesis reaction.

**Synthesis Reactions** One of the easiest reaction types to recognize is a synthesis reaction. In a synthesis reaction, two or more substances combine to form another substance. The generalized formula for this reaction type is as follows:  $A + B \rightarrow AB$ .

The reaction in which hydrogen burns in oxygen to form water is an example of a synthesis reaction.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

This reaction is used to power some types of rockets. Another synthesis reaction is the combination of oxygen with iron in the presence of water to form hydrated iron(II) oxide or rust. This reaction is shown in **Figure 10.** 

**Decomposition Reactions** A decomposition reaction is just the reverse of a synthesis. Instead of two substances coming together to form a third, a **decomposition reaction** occurs when one substance breaks down, or decomposes, into two or more substances. The general formula for this type of reaction can be expressed as follows: AB  $\rightarrow$  A + B.

Most decomposition reactions require the use of heat, light, or electricity. An electric current passed through water produces hydrogen and oxygen as shown in Figure 11.

$$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$$

**Single Displacement** When one element replaces another element in a compound, it is called a single-displacement reaction. Single-displacement reactions are described by the general equation  $A + BC \rightarrow AC + B$ . Here you can see that atom A displaces atom B to produce a new molecule AC. A single displacment reaction is illustrated in **Figure 12**, where a copper wire is put into a solution of silver nitrate. Because copper is a more active metal than silver, it replaces the silver, forming a blue copper(II) nitrate solution. The silver, which is not soluble, forms on the wire.

$$\mathrm{Cu}(s) + 2\mathrm{AgNO}_3(aq) \longrightarrow \mathrm{Cu}(\mathrm{NO}_3)_2 \ (aq) + 2\mathrm{Ag}(s)$$

Reading Checke Describe a single-displacement reaction.



Figure 11 Water decomposes into hydrogen and oxygen when an electric current is passed through it. A small amount of sulfuric acid is added to increase conductivity. Notice the proportions of the gases collected. **Describe** how this is related to the coefficients of the products in the equation.

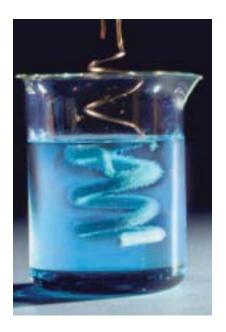


Figure 12 Copper in a wire replaces silver in silver nitrate, forming a blue-tinted solution of copper(II) nitrate.

**Figure 13** This figure shows the activity series of metals. A metal will replace any other metal that is less active.



The Activity Series Sometimes single-displacement reactions can cause problems. For example, if iron-containing vegetables such as spinach are cooked in aluminum pans, aluminum can displace iron from the vegetable. This causes a black deposit of iron to form on the sides of the pan. For this reason, it is better to use stainless steel or enamel cookware when cooking spinach.

We can predict which metal will replace another using the diagram shown in Figure 13, which lists metals according to how reactive they are. A metal can replace any metal below it on the list but not above it. Notice that copper, silver, and gold are the least active metals on the list. That is why these elements often occur as deposits of the relatively pure element. For example, gold is sometimes found as veins in quartz rock. Copper is found in pure lumps known as native copper. Other metals can occur as compounds.

Figure 14 Solid barium sulfate is formed from the reaction of two solutions.

**Observe** *Has a chemical change* occurred in this photo? How can vou tell?



**Double Displacement** In a double-displacement reaction,

the positive ion of one compound replaces the positive ion of the other to form two new compounds. A double-displacement reaction takes place if a precipitate, water, or a gas forms when two ionic compounds in solution are combined. A precipitate is an insoluble compound that comes out of solution during this type of reaction. The generalized formula for this type of reaction is as follows:  $AB + CD \rightarrow AD + CB$ .

#### Reading Check What type of reaction produces a precipitate?

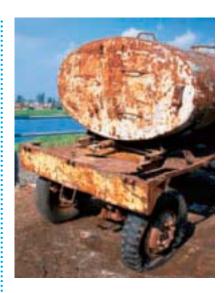
The reaction of barium nitrate with potassium sulfate is an example of this type of reaction. A precipitate—barium sulfate forms, as shown in **Figure 14.** The chemical equation is as follows:

$$Ba(NO_3)_2(aq) + K_2SO_4(aq) \rightarrow BaSO_4(s) + 2KNO_3(aq)$$

These are a few examples of chemical reactions classified into types. Many more reactions of each type occur around you.

**Oxidation-Reduction Reactions** One characteristic that is common to many chemical reactions is the tendency of the substances to lose or gain electrons. Chemists use the term oxidation to describe the loss of electrons and the term reduction to describe the gain of electrons. Chemical reactions involving electron transfer of this sort often involve oxygen, which is very reactive, pulling electrons from metallic elements. Corrosion of metal is a visible result, as shown in **Figure 15.** 

The cause and effect of oxidation and reduction can be taken one step further by describing the substances after the electron transfer. The substance that gains an electron or electrons obviously becomes more negative, so we say it is reduced. On the other hand, the substance that loses an electron or electrons then becomes more positive, and we say it is oxidized. The electrons that were pulled from one atom were gained by another atom in a chemical reaction called reduction. Reduction is the partner to oxidation; the two always work as a pair, which is commonly referred to as redox.



**Figure 15** One of the results of all of these electrons moving from one place to another might show up on the metal body of a tanker.

#### section

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#### **Summary**

#### **Types of Reactions**

- Lavoisier was one of the first scientists to accurately describe a combustion reaction.
- For single-displacement reactions, we can predict which metal will replace another by comparing the activity characteristic of each.
- Some reactions produce a solid called a precipitate when two ionic substances are combined.
- Chemical reactions are organized into five basic classes: combustion, synthesis, decomposition, single displacement, and double displacement.

#### **Oxidation-Reduction Reactions**

- Oxidation is the loss of electrons and reduction is the corresponding gain of electrons.
- Redox reactions often result in corrosion and rust.
- A substance that gains elections is reduced, and a substance that loses elections is oxidized.

#### **Self Check**

- 1. Classify each of the following reactions:
  - a.  $CaO(s) + H_2O \longrightarrow Ca(OH)_2 (aq)$
  - **b.**  $Fe(s) + CuSO_{\Delta}(aq) \longrightarrow FeSO_{\Delta}(aq) + Cu(s)$
  - c.  $NH_4NO_3(s) \longrightarrow N_2O(g) + 2H_2O(g)$
- **2. Describe** what happens in a combustion reaction.
- 3. Explain the difference between synthesis and decomposition reactions.
- **4. Determine**, using **Figure 13**, if zinc will displace gold in a chemical reaction and explain why or why not.
- **5. Think Critically** In the reaction 2 Na +  $Cl_2 \rightarrow 2NaCl$ , which atom is reduced and which atom is oxidized?

#### **Applying Math**

- **6. Use Proportions** The following chemical equation is balanced, but the coefficients used are larger than necessary. Rewrite this balanced equation using the smallest coefficients.
  - $9Fe(s) + 12H_2O(g) \rightarrow 3Fe_3O_4(s) + 12H_2(g)$
- **7. Use Coefficients** Sulfur trioxide, (SO<sub>3</sub>), a pollutant released by coal-burning plants, can react with water in the atmosphere to produce sulfuric acid, H<sub>2</sub>SO<sub>4</sub>. Write a balanced equation for this reaction.

# **Reaction Rates and Energy**

# **Reading Guide**

### What You'll Learn

- Identify the source of energy changes in chemical reactions.
- Compare and contrast exergonic and endergonic reactions.
- **Examine** the effects of catalysts and inhibitors on the speed of chemical reactions.

# Why It's Important

Chemical reactions provide energy to cook your food, keep you warm, and transform the food you eat into substances you need to live and grow.

### Review Vocabulary

chemical bond: the force that holds two atoms together

### New Vocabulary

- activation energy
- endothermic reaction
- exothermic reaction
- rate of reaction
- catalyst
- inhibitor

**Figure 16** When its usefulness is over, a building is sometimes demolished using dynamite. Dynamite charges must be placed carefully so that the building collapses inward, where it cannot harm people or property.



# **Chemical Reactions and Energy**

Often a crowd gathers to watch a building being demolished using dynamite. In a few breathtaking seconds, tremendous structures of steel and cement that took a year or more to build are reduced to rubble and a large cloud of dust. A dynamite explosion, as shown in Figure 16, is an example of a rapid chemical reaction.

All chemical reactions release or absorb energy. This energy can take many forms, such as heat, light, sound, or electricity. The heat produced by a wood fire and the light emitted by a glow stick are two examples of reactions that release energy.

### **Conservation of Energy in Chemical Reactions**

According to the law of conservation of energy, energy cannot be created or destroyed, but can only change form. In compounds, chemical potential energy is stored in chemical bonds between atoms. In some chemical reactions, chemical potential energy is changed to other forms of energy, such as heat or light, and is released. In other chemical reactions, forms of energy such as heat or light are converted to chemical potential energy and stored in bonds that form, and energy is absorbed. In all chemical reactions, energy is never created or destroyed, but only changes form. All reactions follow the laws of conservation of mass and energy.

### **Activation Energy**

As you learned earlier, atoms and molecules have to bump into each other before a product can be formed. In order to form new bonds, atoms have to be close together. In addition to being close, the reactants require a certain amount of energy in order to allow the reaction to start. This minimum amount of energy needed to start a reaction is called activation energy. If there is not enough energy, the reaction will not start. Spilled gasoline does not ignite unless there is an energy source. Once ignited, the gasoline releases enough energy to keep going. Activation energy, which differs from reaction to reaction, is required for both exothermic and endothermic reactions.

# **Endergonic Reactions**

Sometimes a chemical reaction requires more energy to break bonds than is released when new ones are formed. These reactions are called endergonic reactions. The energy absorbed can be in the form of light, heat, or electricity.

Electricity is often used to supply energy to endergonic reactions. For example, electroplating deposits a coating of metal onto a surface.

**Heat Absorption** When the energy needed is in the form of heat, the reaction is called an endothermic reaction. The term endothermic is not just related to chemical reactions. It also can describe physical changes. The process of dissolving a salt in water is a physical change. If you ever had to soak a swollen ankle in an Epsom salt solution, you probably noticed that when you mixed the Epsom salt in water, the solution became cold. The dissolving of Epsom salt absorbs heat. Thus, it is a physical change that is endothermic.

Some reactions are so endothermic that they can cause water to freeze. One such endothermic

reaction is that of barium hydroxide (Ba(OH)<sub>2</sub>) and ammonium chloride (NH<sub>4</sub>Cl) in water, shown in Figure 17.





**Controlling Body Heat** Some animals, such as birds, are classified as endotherms because their body temperature remains constant. An animal whose body temperature varies with its environment, such as a reptile, is classified as an ectotherm. What other animals that can be classified as ectotherms?



**Figure 17** As an endothermic reaction happens, such as the reaction of barium hydroxide and ammonium chloride, energy from the surrounding environment is absorbed, causing a cooling effect. Here, the reaction absorbs so much heat that a drop of water freezes and the beaker holding the reaction sticks to the wood.

Figure 18 With an endothermic reaction, the reactants have a lower energy level than the products. The reactants must overcome the activation energy barrier in order to form new products.

Figure 19 Glow sticks contain

ester and a dye in the outer section and hydrogen peroxide in a center

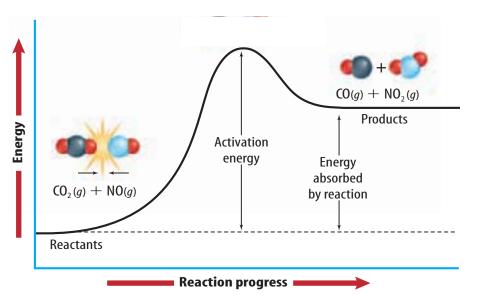
glass tube. Bending the stick breaks

the tube and mixes the three com-

ponents. The energy released is in

the form of visible light.

three different chemicals—an



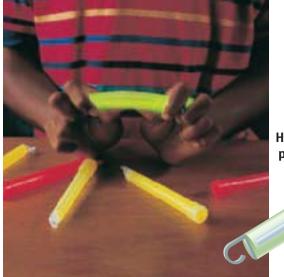
Endothermic Reactions With an endothermic reaction, the chemical reaction will not take place unless energy is added. A constant source of energy must be added to keep the reaction going. The products have more stored energy than the reactants.

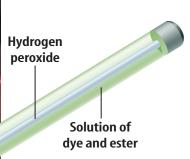
**Figure 18** shows an energy diagram for the reaction of carbon dioxide (CO<sub>2</sub>) and nitrogen monoxide (NO). With an endothermic reaction, the reactants have a lower energy level than the products. In order for the products to form, an input of energy is needed for the reactants to overcome the activation energy barrier.

# **Exergonic Reactions**

You have seen many reactions that release energy. Chemical reactions that release energy are called exergonic (ek sur GAH nihk) reactions. In these reactions, less energy is required to

> break the original bonds than is released when new bonds are formed. As a result, some form of energy, such as light or heat, is given off by the reaction. The familiar glow from the reaction inside a glow stick, shown in Figure 19, is an example of an exergonic reaction, which produces visible light. In other reac-



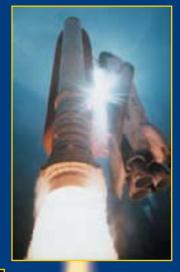


tions, however, energy is released as heat. This is the case with some heat packs that are used to treat muscle aches and other medical conditions. Another release of energy is used to power rockets, as shown in **Figure 20.** 

# NATIONAL GEOGRAPHIC VISUALIZING CHEMICAL ENERGY

### Figure 20

ockets burn fuel to provide the thrust necessary to propel them upward. In 1926, engineer Robert Goddard used gasoline and liquid oxygen to propel the first ever liquid-fueled rocket. Although many people at the time ridiculed Goddard's space travel theories, his rockets eventually served as models for those that have gone to the Moon and beyond. A selection of rockets—including Goddard's—is shown here. The number below each craft indicates the amount of thrust—expressed in newtons (N)—produced during launch.



SPACE SHUTTLE The main engines produce enormous amounts of energy by combining liquid hydrogen and oxygen. Coupled with solid rocket boosters, they produce over 32.5 million newtons (N) of thrust to lift the system's 2 million kg off the ground.

JUPITER C This rocket launched the first United States satellite in 1958. It used a fuel called hydyne plus liquid oxygen.

▼ GODDARD'S MODEL
ROCKET Although his
first rocket rose only
12.6 m, Goddard successfully launched 35 rockets
in his lifetime. The highest reached an altitude
of 2.7 km.



400 N

LUNAR MODULE Smaller rocket engines, like those used by the Lunar Module to leave the Moon, use hydrazine-peroxide fuels. The number shown below indicates the fixed thrust from one of the module's two engines; the other engine's thrust was adjustable.



369,350 N

32,500,000 N

15,920 N



### **Creating a Colorful Chemical Reaction**

#### **Procedure**



- 1. Complete the safety form.
- **2.** Sprinkle a few crystals of copper(II) bromide into the **test tube**. Record the color of the crystals in your Science Journal.
- 3. Pour 5 mL of water into the test tube. Record your observations.
- **4.** Slowly add more water and observe and record what happens.

### **Analysis**

- 1. What color were the crystals after water was added?
- 2. What color were they when you added more water?
- 3. What caused this color change?

**Figure 21** In an exothermic reaction, molecules have enough energy to overcome the activation energy barrier. Energy is released with the formation of new products.

**Exothermic Reactions** When the energy given off in a reaction is primarily in the form of heat, the reaction is called an exothermic reaction. The burning of wood and the explosion of dynamite are exothermic reactions. Iron rusting is also exothermic, but, under typical conditions, the reaction proceeds so slowly that it's difficult to detect any temperature change.



Why is a log fire considered to be an exothermic

Exothermic reactions provide most of the power used in homes and industries. Fossil fuels that contain carbon, such as coal, petroleum, and natural gas, combine with oxygen to yield carbon dioxide gas and energy. Unfortunately impurities in these fuels, such as sulfur, burn as well, producing pollutants such as sulfur dioxide. Sulfur dioxide combines with water in the atmosphere, producing acid rain.

**Energy Release** The energy diagram for an exothermic reaction is the reverse of an endothermic reaction. With an exothermic reaction, the products have less stored energy than the reactants. As shown in **Figure 21**, the reactants, carbon monoxide (CO) and nitrogen dioxide (NO<sub>2</sub>) have a higher energy level than the products. The molecules have enough energy to overcome the activation energy barrier.

### **Chemical Reaction Rates**

According to the kinetic theory of matter, atoms and molecules are always moving. In order for a chemical reaction to occur, the atoms and molecules that are the reactants have to bump into each other or collide. The rate of reaction is the speed at which reactants are consumed and products are produced in a given reaction.

Activation  $CO(q) + NO_{2}(q)$ energy Reactants Energy released by reaction  $CO_{2}(q) + NO(q)$ **Products** 

Reaction progress

Reaction rate is important in the manufacturing industry because the faster the product can be made, the less it usually costs. Sometimes a fast reaction rate is undesirable, such as the rate of reaction that causes food spoilage. In this case, the slower the reaction rate, the longer the food will stay edible. What conditions control the reaction rate, and how can the rate be changed?

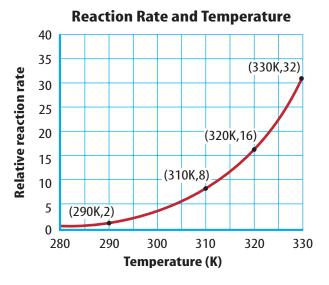
**Temperature** Energy is needed by atoms and molecules to break old bonds and to form new ones. One way to increase the activation energy is to add heat or increase the temperature. With an increase in temperature, atoms and molecules move faster and kinetic energy increases. With faster moving atoms and molecules, more molecules have kinetic energy greater than activation energy. The atoms and molecules now will have enough energy to break old bonds at higher temperature, which will increase the reaction rate. A chemical reaction will go faster at higher temperature and slower at lower temperature as shown in **Figure 22.** 

**Concentration** When you walk through the hallways at school, you are more likely to bump into another student if the hallways are crowded. A similar situation is shown in **Figure 23.** The closer atoms and molecules are to each other, the greater the chance of collision. The amount of substance present in a certain volume is called its concentration. Increasing the concentration of a substance increases the reaction rate.

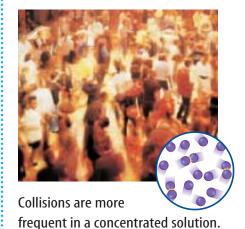
**Surface Area** Only atoms or molecules in the outer layer of a substance can collide with other reactants. When a substance is finely divided, it has a larger surface area than when it was whole. Increasing the surface area increases the chance for collisions, which will increase the reaction rate. A powdered reactant will produce a faster reaction rate than a lump of the same reactant. For instance, grain elevator operators have to be careful of explosions and fire. The dust from the grains in the bin has a larger surface area than the whole grains. With an ignition spark, the dust will catch fire rapidly and cause an explosion.

**Agitation** If you are making lemonade, the water, sugar, and lemon juice are mixed in order to get the product. Agitation or stirring is a physical process that allows reactants to mix. A low stirring rate will slow the reaction due to fewer collisions. Chemical reactions can be controlled by agitation.

**Pressure** Another way to influence the reaction rate is with pressure. By increasing the pressure of gases, molecules have less room to move about and the concentration of the reactants increases. This will boost the chance of collisions, which means the reaction rate increases. Decreasing the pressure means fewer collisions, and lower reaction rate.



**Figure 22** Increasing the temperature of a reaction increases the frequency of collisions, which will increase the rate of reaction.



Collisions are less frequent in a dilute solution.

**Figure 23** People are more likely to collide in crowds. Molecules behave similarly.



Catalysts Metals, such as platinum and palladium, are used as catalysts in the exhaust systems of automobiles. What reactions do you think they catalyze?

**Catalysts and Inhibitors** Some reactions proceed too slowly to be useful. To speed them up, a catalyst reaction can be added. A **catalyst** is substance that speeds up a chemical reaction without being permanently changed itself. When you add a catalyst to a reaction, the mass of the product that is formed remains the same, but it will form more rapidly. A catalyst lowers the activation energy of the reaction. With the lowering of the activation energy, collisions among molecules now will become more effective, thus increasing the rate of reaction.

Reading Checks Explain how a catalyst speeds up a reaction.

At times, it is worthwhile to prevent certain reaction from occurring. Substances that are used to slow down a chemical reaction are called **inhibitors**. The food preservations BHT and BHA are inhibitors that prevent spoilage of certain foods, such as cereals and crackers.

One thing to remember when thinking about catalysts and inhibitors is that they do not change the amount of product produced. They only change the rate of production. Catalysts increase the rate and inhibitors decease the rate. Other factors, including concentration, pressure, and temperature, also affect the rate of reaction and must be considered when catalyzing or inhibiting a reaction.

### section

### review

### **Summary**

### **Conservation of Energy**

• In a chemical reaction, the total amount of energy is the same. Energy is neither created nor destroyed.

### **Chemical Reactions and Energy**

- Chemical reactions release or absorb energy, as chemical bonds are broken and formed.
- An endothermic reaction absorbs heat.
- An exothermic reaction releases heat.

#### **Chemical Reaction Rates**

- Temperature, concentration, and pressure can affect reaction rates.
- In an exothermic reaction, reactants have more energy than the products.
- In an endothermic reaction, the reactants have less energy than the products.

### **Self Check**

- 1. Explain whether the term endothermic can be used to describe physical changes.
- **2. Describe** how temperature can affect reaction rate.
- 3. **Illustrate** As an exothermic reaction, methane and oxygen will react to form carbon dioxide and water. Draw the activation energy chart showing where the reactants and products belong.
- **4. Explain** why crackers containing BHT stay fresh longer than those without it.
- **5. Think Critically** To develop a product that warms people's hands, would you choose an exothermic or endothermic reaction to use? Why?

### **Applying Math**

- **6. Calculate** If an endothermic reaction begins at 26°C and loses 2°C per minute, how long will it take to reach 0°C?
- **7. Use Graphs** Create a graph of the data in guestion 6. After 5 min, what is the temperature of the reaction?



# To Glow or Not to Glow

Many chemical reactions release energy as light. The light seen from a light stick is the result of a chemical reaction.

### Real-World Problem-

How does changing the water temperature affect the amount of light produced from a light stick?

### Goals

- Observe the effect of temperature on a light stick.
- **Explain** how temperature affects the rate of reaction.

### **Possible Materials**

light sticks (3) 400-mL beakers (4) water ice hot plate thermometer graduated cylinder

### **Safety Precautions**



### Procedure

- 1. Complete the safety form before you begin.
- **2.** Write a hypothesis in your Science Journal about how the light stick will be affected by temperature.
- **3.** Prepare a hot water bath by pouring 200-mL of hot water into a beaker. Record the temperature of the hot water.
- **4.** Prepare a 200-mL ice water bath and a 200-mL room temperature water bath. Record the temperature of the water in each bath.



- 5. Bend a light stick until the inner capsule snaps. Shake the light stick for 10 seconds. Place the light stick into the hot water bath. Record your observations.
- Repeat step 5 with the remaining light sticks using the ice water bath and the room temperature bath, instead. Record your observations.

# Conclude and Apply-

- 1. Summarize your observations.
- **2. Explain** why the amount of light released is different above and below the water level.
- **3. Evaluate** your hypothesis.
- **4. Infer** how temperature affects the light intensity.

# Communicating Your Data

Compare your results with those of your classmates. For more help refer to the Science Skill Handbook.



# **Investigating Reaction Conditions**

### Goals

- Evaluate the effect of concentration on the rate of a chemical reaction.
- **Examine** the effect of temperature on the rate of a chemical reaction.

### **Materials**

water
vinegar solution
baking soda
balloons (3)
plastic 0.5-liter soft-drink
bottles (3)
test tube
150-mL beakers (3)
100-mL graduated cylinder
marker
tape measure
stop watch
\*clock with second hand
\*Alternate material

### **Safety Precautions**



# Real-World Problem

Many people believe that you cannot perform chemical reactions without expensive equipment or costly chemicals. But this isn't true; chemical reactions happen everywhere. All you need is a food store to find many substances that can produce exciting chemical reactions. What factors determine how much product is produced in a chemical reaction or how fast a reaction occurs?

### Procedure

- 1. Complete the safety form before you begin.
- **2.** Copy the data tables into your Science Journal.
- **3.** Prepare the following solutions: a 50% vinegar solution by mixing 50 mL of vinegar with 50 mL of water; a 30% vinegar solution by mixing 30 mL vinegar with 70 mL of water and a 10% vinegar solution by mixing 10 mL of vinegar with 90 mL of water. Pour these solutions into labeled 0.5-L plastic bottles.
- **4.** Mark a small test tube about 1—2 cm from its bottom. Fill the test tube to the line with baking soda. Pour the baking soda into one balloon. Repeat, adding baking soda to the other two balloons.



# Using Scientific Methods

- **5.** Place the mouth of one balloon over the mouth of one 0.5-L bottle. Do not let any of the baking soda fall into the solution.
- **6.** Lift each balloon to allow the baking soda to fall into each vinegar solution. Observe time of reaction and measure how much each balloon inflates. Record your observations in your data table.
- 7. Rinse the plastic bottles with water. Prepare three 30% vinegar solutions. Bottle A will have cold water added. Bottle B will have room temperature water added. Bottle C will have hot water added.
- 8. Prepare the baking soda in the balloons as in step 3. Add the baking soda to the solution. Time how long it takes for the reaction to finish. Measure how much each balloon inflates. Record your observations in the data table.

Concentration Table			
Concentration	50%	30%	10%
Observations	Do not	write in thi	s book.

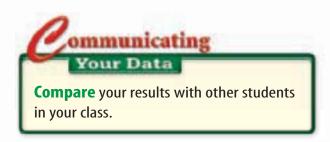
Temperature Table			
Temperature	Cold Temp	Room Temp	Hot Temp
Observations	Do not	write in thi	s book.

# Analyze Your Data-

- **1. Describe** how increasing the concentration of a solution affects the rate of a chemical reaction.
- **2. Summarize** how temperature affects the rate of a chemical reaction.
- **3. Explain** why the balloons became inflated.

# Conclude and Apply

- **1. Infer** how a change in pressure can affect the rate of chemical reaction of this system.
- **2. Explain** how temperature and balloon inflation are related.





# Accidents in SCIENCE

SOMETIMES
GREAT
DISCOVERIES
HAPPEN BY
ACCIDENT!

# A Clumsy Move Pays Off

reat scientific discoveries can happen in some very unlikely ways. Most people might not think that an accidental spill left uncleaned would become significant, but that's exactly what led a chemist named Hilaire de Chardonnet (hee LAYR • duh • shar doh NAY) to his discovery. In 1878, Chardonnet accidentally knocked over some nitrate chemicals. He put off cleaning up the

Silk is produced naturally by silkworms. In the mid-1800s, though, silkworms were dying from disease and the silk industry was suffering. Businesses were going under and people were put out of work. Many scientists were working to develop a solution to this problem. Chardonnet had been searching for a silk substitute for years—he just didn't plan to find it by knocking it over!

mess and ended up inventing artificial silk.





Hilaire de Chardonnet

# **A Messy Discovery**

Chardonnet was in his darkroom developing photographs when the accidental spill took place. He decided to clean up the spill later and finish what he was working on. By the time he returned to wipe up the spill, the chemical solution had turned into a thick, gooey mess. When he pulled the cleaning cloth away, the goop formed long, thin strands of fiber that stuck to the cloth. The chemicals had reacted with the cellulose in the wooden table and liquefied it. The strands of fiber looked just like the raw silk made by silkworms.

Within six years, Chardonnet had developed a way to make the fibers into an artificial silk. Other scientists extended his work, developing a fiber called rayon. Today's rayon is made from sodium hydroxide mixed with wood fibers, which is then stranded and woven into cloth.

Rayon has another real-world application. To help prevent counterfeiting, dollars are printed on paper that contains red and blue rayon fibers. If you can scratch off the red or blue, that means it's ink and your bill is counterfeit. If you can pick out the red or blue fiber with a needle, it's a real bill.

**Create** Work with a partner to examine the fabric content labels on the inside collars of your clothes. Research the materials, then make a data table that identifies their characteristics.

For more information, visit gpescience.com

### Reviewing Main Ideas

### **Section 1 Chemical Changes**

- **1.** In a chemical reaction, one or more substances are changed to new substances.
- **2.** The substances that react are called reactants, and the new substances formed are called products. Charcoal, the reactant shown below, is almost pure carbon.



- **3.** The law of conservation of mass states that in chemical reactions, matter is neither created nor destroyed, just rearranged.
- **4.** The law of conservation of energy states that energy is neither created nor destroyed.

# **Section 2 Chemical Equations**

- **1.** Balanced chemical equations give the exact number of atoms involved in the reaction.
- **2.** A balanced chemical equation has the same number of atoms of each element on both sides of the equation. This satisfies the law of conservation of mass.
- **3.** When balancing chemical equations, change only the coefficients of the formulas, never the subscripts. To change a subscript would change the compound.

### Section 3

# Classifying Chemical Reactions

- **1.** In synthesis reactions, two or more substances combine to form another substance.
- **2.** In single-displacement reactions, one element replaces another in a compound.
- **3.** In double-displacement reactions, ions in two compounds switch places, often forming a gas or insoluble compound.
- **4.** Using the activity series chart, scientists can determine which metal can replace another metal.

### Section 4 Reaction Rates and Energy

- **1.** When energy is released in the form of heat, the reaction is exothermic. An
  - endothermic reaction requires heat to get started. This flame is releasing light and heat energy.
- 2. Temperature, concentration, and the presence of a catalyst can change the rate of reaction.



- **3.** Activation energy is the minimum amount of energy needed to start a reaction.
- **4.** Reactions may be sped up by adding catalysts, such as a nickel catalyst. A reaction can be slowed down by adding inhibitors.

FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review chemical reactions.

### **Using Vocabulary**

- activation energy p.735
  balanced chemical
  equation p.726
  catalyst p.740
  chemical equation p.723
  chemical reaction p.720
  combustion reaction
  p.730
  decomposition reaction
  p.731
  double-displacement
  reaction p.732
- endothermic reaction
  p. 735
  exothermic reaction
  p. 738
  inhibitor p. 740
  product p. 720
  rate of reaction p. 738
  reactant p. 720
  single-displacement
  reaction p. 731
  synthesis reaction

p. 731

For each set of vocabulary words below, explain the relationship that exists.

- 1. synthesis reaction—decomposition reaction
- 2. reactant—product
- 3. catalyst—inhibitor
- 4. exothermic reaction—endothermic reaction
- 5. chemical reaction—product
- **6.** single-displacement reaction—double-displacement reaction
- 7. chemical reaction—synthesis reaction

### **Checking Concepts**

Choose the word or phrase that best answers the question.

- **8.** Oxygen gas is always written as O<sub>2</sub> in chemical equations. What term is used to describe the "2" in this formula?
  - A) catalyst
- **c)** product
- **B)** coefficient
- **D)** subscript
- **9.** In an endothermic reaction, which has the lower energy?
  - **A)** catalyst
- **C)** product
- **B)** inhibitor
- **D)** reactant

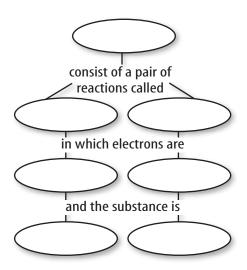
- **10.** What law is based on the experiments of Lavoisier?
  - **A)** atomic theory
  - **B)** collision theory
  - **c)** conservation of energy
  - **D)** conservation of mass
- **11.** What must an element be in order to replace another element in a compound?
  - **A)** less inhibiting
- **c)** more inhibiting
- **B)** less reactive
- **D)** more reactive
- **12.** How do you indicate that a substance in an equation is a solid?
  - A) (l)
- **C)** (s)
- **B)** (g)
- **D)** (aq)
- **13.** Classify the reaction:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$
.

- A) combustion
- **B)** decomposition
- c) single displacement
- **D)** synthesis
- **14.** What compound is the food additive BHA?
  - **A)** catalyst
- **c)** oxidized
- **B)** inhibitor
- **D)** reduced
- **15.** Which symbol indicates that a substance is dissolved in water when writing an equation?
  - $\mathbf{A})$  (aq)
- **c)** (g)
- **B)** (s)
- **D)** (*l*)
- **16.** What word would you use to describe HgO in the reaction that Lavoisier used to show conservation of mass?
  - A) catalyst
- **c)** product
- **B)** inhibitor
- **D)** reactant
- **17.** When hydrogen burns, what is oxygen's role?
  - **A)** catalyst
- **c)** product
- **B)** inhibitor
- **D)** reactant

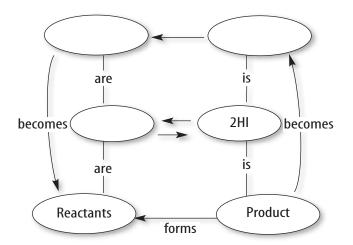
### Interpreting Graphics

**18.** Copy and complete the concept map using the following terms: oxidized, redox reactions, lost, reduced, oxidation, gained, and reduction.



**19. Sequence** Sometimes a bond formed in a chemical reaction is weak and the product breaks apart as it forms. This is shown by a double arrow in chemical equations. Copy and complete the concept map, using the words *product(s)* and *reactant(s)*. In the blank in the center, fill in the formulas for the substances appearing in the reversible reaction.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$



### **Thinking Critically**

- **20.** Write a balanced chemical equation for the reaction of propane  $C_3H_8(g)$  burning in oxygen to form carbon dioxide and water vapor.
- **21. Interpret** the balanced chemical equation from question 23 to explain the law of conservation of mass.
- **22.** Hypothesize Zn is placed in a solution of Cu(NO<sub>3</sub>)<sub>2</sub> and Cu is placed in a Zn(NO<sub>3</sub>)<sub>2</sub> solution. In which of these will a reaction occur?
- 23. Predict what kind of energy process happens when lye, NaOH(s), is put in water and the water gets hot.
- **24.** Recognize Cause and Effect Sucrose, or table sugar, is a disaccharide. This means that sucrose is composed of two simple sugars chemically bonded together. Sucrose can be separated into its components by heating it in an aqueous sulfuric acid solution. Research what products are formed by breaking up sucrose. What role does the acid play?
- **25.** Classify Make an outline with the general heading *Chemical Reactions*. Include the five types of reactions, with a description and example of each.

### **Applying Math**

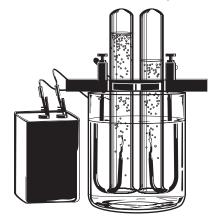
- **26.** Use Numbers When 46 g of sodium were exposed to dry air, 62 g of sodium oxide formed. How many grams of oxygen from the air were used?
- **27.** Calculate Mass Chromium is produced by reacting its oxide with aluminum. If 76 g of Cr<sub>2</sub>O<sub>3</sub> and 27 g of Al completely react to form 51 g of Al<sub>2</sub>O<sub>3</sub>, how many grams of Cr are formed?

# chapter 23 Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

### Multiple Choice

### Use the illustration below to answer question 1.



1. The illustration above shows a chemical reaction in which water decomposes into hydrogen gas and oxygen gas when an electric current is passed through it. Which of the following is the correct chemical equation for this reaction?

**A.** 
$$H_2O(l) \rightarrow H_2(g) + O(g)$$

**B.** 
$$H_2O(l) \rightarrow 2H(g) + O(g)$$

**c.** 
$$2H_2O(l) \rightarrow 2H_2(g) + 2O(g)$$

**D.** 
$$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$$

**2.** Which substance is the precipitate in the following reaction?

$$Ba(NO_3)_2(aq) + K_2SO_4(aq) \rightarrow BaSO_4(s) + 2KNO_3(aq)$$

**A.** 
$$Ba(NO_3)_2$$

**B.** 
$$K_2SO_4$$

**D.** 
$$KNO_3$$

- **3.** Which reaction is endothermic?
  - A. iron rusting
  - **B.** burning wood
  - **c.** exploding dynamite
  - **D.** mixing Epsom salt in water

### Use the figure below to answer question 4.



- **4.** Which metal would most likely replace lead in a solution?
  - A. potassium
  - **B.** copper
  - **c.** silver
  - **D.** gold
- **5.** Which type of reaction is the opposite of a synthesis reaction?
  - A. displacement
  - **B.** reversible
  - **c.** combustion
  - **D.** decomposition

### Gridded Response

- **6.** A reaction of 24 g of sodium hydroxide with 20 g of hydrogen chloride gives off 12 g of water. What mass of sodium chloride is formed in this reaction?
- **7.** From an experiment to separate water into hydrogen and oxygen, a student collected 10.0 g of hydrogen and 79.4 g of oxygen. How much water was originally involved in the process?

### Short Response

**8.** What is a synthesis reaction?

Use the illustration to answer question 9.



**9.** The illustration above shows the reaction of aqueous nickel(II) chloride, NiCl<sub>2</sub>, and aqueous sodium hydroxide, NaOH, to form solid nickel(II) hydroxide, Ni (OH)<sub>2</sub>, and aqueous sodium chloride, NaCl. State the conversation of mass as it applies to this chemical reaction.

**10.** Food preservatives are a type of inhibitor. Explain why this is useful in foods.

### Extended Response

**11.** Explain what is wrong with the following balanced equation:

$$4Al(s) + 6O(g) \rightarrow 2Al_2O_3(s)$$

What is the correct form of the equation?

Use the illustration to answer question 12.



- **12.** The drawing above illustrates a chemical reaction between magnesium, Mg, and oxygen gas, O<sub>2</sub>. This reaction is exergonic and exothermic. Explain what these terms mean and how you can tell that a chemical reaction is exergonic or exothermic.
- **13.** The reaction of magnesium and oxygen gas forms magnesium oxide, MgO. Write the chemical equation for this reaction and explain the process you use to balance the equation.

### Test-Taking Tip

Missing Information Questions often will ask about missing information. Notice what is missing as well as what is given.

# chapter

# 24

### BIG (Idea

A solution is a homogeneous mixture of a solvent and a solute.

### **24.1 How Solutions Form**

MAIN (Idea A solution forms when particles of solute become evenly mixed among particles of solute.

# 24.2 Solubility and Concentration

MAIN (Idea Solubility is the maximum amount of solute that can dissolve and concentration is the amount of solute actually dissolved in a given amount of solute.

# 24.3 Acids, Bases, and Salts

MAIN (Idea An acid and a base react to form a salt and water.

# 24.4 Strength of Acids and Bases

MAIN (Idea An acid or base is considered strong if nearly all of its molecules dissociate into ions in water.

### Mixed-Up Chemistry

Seawater, lemonade, and suntan lotion are liquids. They have something else in common, too—they are all solutions. In this chapter, you will learn about solutions.

### **Science Journal**

Are all liquids necessarily solutions, and are all solutions liquids? Check your answer later and revise it if you've learned differently.



# **Start-Up Activities**



### **Magic Solutions**

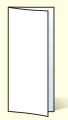
To prevent spies from learning military secrets, scientists developed a special ink that is invisible on paper at room temperature. When the paper is warmed by a candle or lightbulb, the message appears. In this lab, you will create an invisible message.

- 1. Complete the safety form.
- Write a message or draw a picture on a white sheet of paper using a cotton swab dipped in either phenolphthalein indicator or universal indicator. In your Science Journal, record which indicator you used.
- **3.** Allow the paper to dry thoroughly.
- 4. Dip a clean cotton ball in household ammonia (a base) or vinegar (an acid) and rub it across your paper. Record which solution you used and your observations in your Science Journal.
- **5.** Compare your results with those of others.
- **6. Think Critically** In your Science Journal, infer how the magic solution works.



Solutions, Acids, and Bases
Make the following Foldable
to help you identify the main
characteristics of solutions, acids,
and bases.

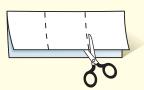
Fold a sheet of paper vertically from side to side. Make the front edge about 1.25 cm longer than the back edge.



STEP 2 Turn lengthwise and fold into thirds.



STEP 3 Unfold and cut only the top layer along both folds to make three tabs.



STEP 4 Label each tab.



**Reading for Main Ideas** As you read the chapter, list the characteristics of solutions, acids, and bases.



Preview this chapter's content and activities at gpescience.com

# **How Solutions Form**

# **Reading Guide**

### What You'll Learn

- Identify the components of a solution.
- **Explain** how things dissolve.
- **Identify** the factors that affect the rates at which solids and gases dissolve in liquids.

# Why It's Important

Solutions play an important role in your everyday life. Examples of everyday solutions are sports drinks, dishwashing detergents, and shampoos.

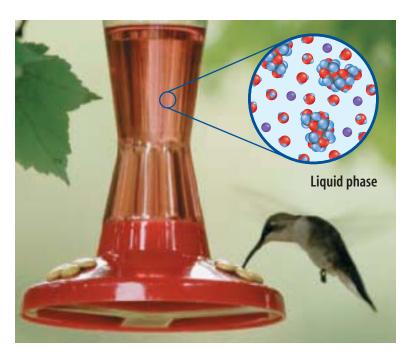
### Review Vocabulary

homogeneous mixture: solid, liquid, or gas that contains two or more substances blended evenly throughout

### New Vocabulary

- solution
- solute
- solvent
- aqueous solution

### **Figure 1** The liquid solution in the hummingbird feeder contains sugar, food coloring, and other substances.



### What is a solution?

Hummingbirds are fascinating creatures. They can hover for long periods while they sip nectar from flowers through their long beaks. To attract hummingbirds, many people use feeder bottles containing a red liquid, as shown in **Figure 1.** The liquid is a solution of sugar and red food coloring in water.

Suppose you are making some hummingbird food. When you

add sugar to water and stir, the sugar crystals disappear. When you add a few drops of red food coloring and stir, the color spreads evenly throughout the sugar water. Why does this happen?

Hummingbird food is one of many solutions. A **solution** is a mixture that has the same composition, color, density, and even taste throughout. The reason you no longer see the sugar crystals and the reason the red dye spreads out evenly is that they have formed a completely homogeneous mixture. The sugar crystals broke up into sugar molecules, the red dye into its molecules, and both mixed evenly among the water molecules.

# **Solutes and Solvents**

In a solution, one substance is dissolved in another. In the hummingbird solution, sugar which is the substance being dissolved, is the **solute**. Water, which is the substance doing the dissolving, is the solvent. When a solid dissolves in a liquid, the solid is the solute and the liquid is the solvent. In salt water, salt is the solute and water is the solvent. In carbonated soft drinks, carbon dioxide gas is one of the solutes and water is the solvent. When a liquid dissolves in another liquid, the substance present in the larger amount is usually called the solvent. A solution in which water is the solvent is called an aqueous (A kwee us) solution.

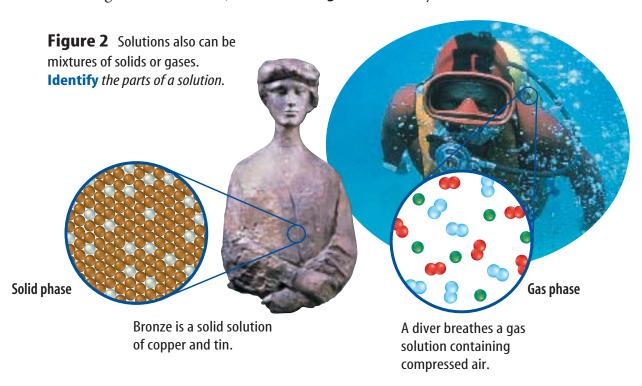


How do you know which substance is the solute in a solution?

**Nonliquid Solutions** Solutions also can be gaseous or even solid. Examples are shown in Figure 1 and Figure 2. Did you know that the air you breathe is a solution? In fact, all mixtures of gases are solutions. Air is a solution of 78 percent nitrogen, 21 percent oxygen, and small amounts of other gases such as argon, carbon dioxide, and hydrogen. The sterling silver and brass used in musical instruments are an example of a solid solution. The sterling silver contains 92.5 percent silver and 7.5 percent copper. The brass is a solution of copper and zinc metals. Solid solutions are known as alloys. They are made by melting the metal solute and solvent together. Most coins, as shown in **Figure 3**, are alloys.



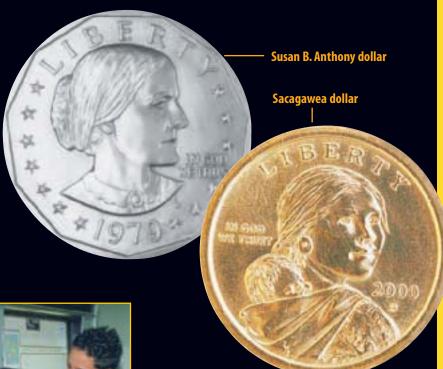
**Surface-Coating Chemist** A scientist who develops products such as house paints and polyurethane wood finishers is called a surface-coating chemist. Paints, varnishes, and synthetic clear coatings are solutions. These products are designed to protect the surface of an object from the environment. Make a list of five items that have a protective coating that was applied as a solution.



# NATIONAL GEOGRAPHIC VISUALIZING METAL ALLOYS

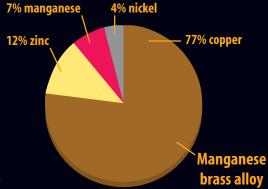
### Figure 3

ave you ever accidentally put a non-United States coin into a vending machine? Of course, the vending machine didn't accept it. If a vending machine is that selective, how can it be fooled by two coins that look and feel very different? This is exactly the case with the silver Susan B. Anthony dollar and the new golden Sacagawea dollar. Vending machines can't tell them apart.





✓ Vending machines recognize coins by size, weight, and electrical conductivity. The size and weight of the Susan B. Anthony coin were easy to copy. Copying the coin's electrical conductivity was more difficult.



▲ The dollar's copper core is half the coin's thickness. It is sandwiched between two layers of manganese brass alloy.

Manganese brass alloy Copper core Manganese brass alloy

Over 30,000 samples of coin coatings were tested to find an alloy and thickness that would copy the conductivity of the Susan B. Anthony dollar. The final composition of the alloy is shown in the graph above. The key ingredient? Manganese.

### **How Substances Dissolve**

Fruit drinks and sports drinks are examples of solutions made by dissolving solids in liquids. Like hummingbird food, both contain sugar as well as other substances that add color and flavor. How do solids such as sugar dissolve in water?

The dissolving of a solid in a liquid occurs at the surface of the solid. To understand how water solutions form, keep in mind two things you have learned about water. Like the particles of any substance, water molecules are constantly moving. Also, water molecules are polar, which means they have a positive area and a negative area. Molecules of sugar also are polar.

**How It Happens** Molecules of sugar dissolving in water are shown in **Figure 4.** First, water molecules cluster around sugar molecules with their negative ends attracted to the positive ends of the sugar. Then, the water molecules pull the sugar molecules into solution. Finally, the water molecules and the sugar molecules mix evenly, forming a solution.

Reading Check

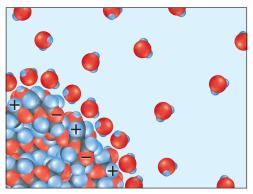
How do water molecules help sugar molecules dissolve?

The process described in **Figure 4** repeats as layer after layer of sugar molecules move away from the crystal, until all the molecules are evenly spread out. The same three steps occur for most solid solutes dissolving in a liquid solvent.

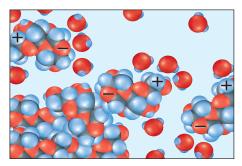
**Dissolving Liquids and Gases** The same process takes place when a gas dissolves in a liquid. Particles of liquids and gases move much more freely than do particles of solids. When gases dissolve in gases or when liquids dissolve in liquids, this movement spreads solutes evenly throughout the solvent, resulting in a homogenous solution.

Dissolving Solids in Solids How can you mix solids to make alloys? Although solid particles do move a little, this movement is not enough to spread them evenly throughout the mixture. The solid metals are first melted and then mixed together. In this liquid state, the metal atoms can spread out evenly and will remain mixed when cooled.

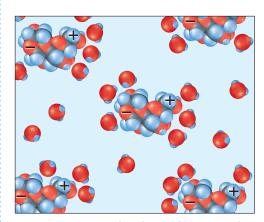
**Figure 4** Dissolving sugar in water can be thought of as a three-step process.



**Step 1** Moving water molecules cluster around the sugar molecules as their negative ends are attracted to the positive ends of the sugar molecules.



**Step 2** Water molecules pull the sugar molecules into solution.



Step 3 Water molecules and sugar molecules spread out to form a homogeneous mixture.



### **Observing the Effect** of Surface Area

#### **Procedure**

### 

- **1.** Complete the safety form.
- 2. Grind up two sugar cubes.
- **3.** Place the ground sugar particles into a mediumsized glass and place two unground sugar cubes into a similar glass.
- **4.** Add an equal amount of water at room temperature to each glass.

### **Analysis**

- 1. Compare the times required to dissolve each.
- 2. What can you conclude about the dissolving rate and surface area?

### **Rate of Dissolving**

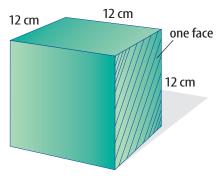
When two substances form a solution, the dissolving occurs at different rates. Sometimes the rate at which a solute dissolves into a solvent is fast, while other times it is slow. There are several things you can do to speed up the rate of dissolving stirring, reducing crystal size, and increasing temperature.

**Stirring** How does stirring speed up the dissolving process? Think about how you make a drink from a powdered mix. After you add the mix to water, you stir it. Stirring a solution speeds up the dissolving process because it brings more fresh solvent into contact with more solute. The fresh solvent attracts the particles of solute, causing the solid solute to dissolve faster.

**Crystal Size** Another way to speed the dissolving of a solid in a liquid is to grind large crystals into smaller ones. Suppose you want to use a 5-g crystal of rock candy to sweeten your water. If you put the whole crystal into a glass of water, it might take several minutes to dissolve, even with stirring. However, if you first grind the crystal of rock candy into a powder, it will dissolve in the same amount of water in a few seconds.

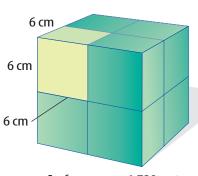
Why does breaking up a solid cause it to dissolve faster? Breaking the solid into many smaller pieces greatly increases its surface area, as you can see in **Figure 5.** Because dissolving takes place at the surface of the solid, increasing the surface area allows more solvent to come into contact with more solid solute. Therefore, the speed of the dissolving process increases.

Figure 5 Crystal size affects solubility. Large crystals dissolve in water slowly.



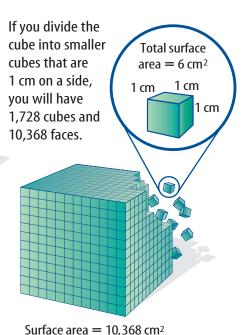
Surface area  $= 864 \text{ cm}^2$ 

A face of a cube is the outer surface that has four edges.



Surface area =  $1,728 \text{ cm}^2$ 

Pull apart the cube into smaller cubes of equal size. You now have 8 cubes and 48 faces.



# **Applying Math**

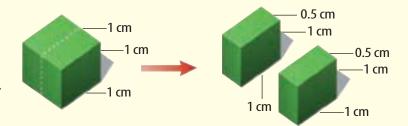
### **Calculate**

**SURFACE AREA** The length, height, and width of a cube are each 1 cm. If the cube is cut in half to form two rectangles, how much new surface area has been created?

### **IDENTIFY** the known values and the unknown value

Identify the known values:

- The cube has dimensions of l = h = w = 1 cm.
- The rectangular solid has a width w = 0.5 cm.
- The rectangular solid has a length and height l = h = 1 cm.



• The cube and the rectangular solids each have six faces: front and back  $(h \times w)$ ; left and right  $(h \times l)$ ; and top and bottom  $(w \times l)$ . The total surface area of the cube or the rectangular solid is the sum of these areas, or  $2(h \times w) + 2(h \times l) + 2(w \times l)$ .

Identify the unknown value:

Find the total surface area of the two rectangular solids.

**SOLVE** the problem

The surface area of the cube is:

$$2(1 \text{ cm} \times 1 \text{ cm}) + 2(1 \text{ cm} \times 1 \text{ cm}) + 2(1 \text{ cm} \times 1 \text{ cm}) = 6 \text{ cm}^2$$

The surface area of the rectangular solid is:

$$2(1 \text{ cm} \times 0.5 \text{ cm}) + 2(1 \text{ cm} \times 1 \text{ cm}) + 2(0.5 \text{ cm} \times 1 \text{ cm}) = 4 \text{ cm}^2$$

Because there are two rectangular solids, their total surface area is:

$$4 \text{ cm}^2 + 4 \text{ cm}^2 = 8 \text{ cm}^2$$

To find out how much new surface area has been created, compare the two results:  $8 \text{ cm}^2 - 6 \text{ cm}^2 = 2 \text{ cm}^2$ 

CHECK the answer

Does your answer seem reasonable? Consider what you've done by splitting the cube in two. You have created two new faces, each with a surface area of 1 cm<sup>2</sup>; therefore, the answer 2 cm<sup>2</sup> is correct.

### **Practice Problems**

- 1. A cube of salt with a length, height, and width of 5 cm is attached along a face to another cube of salt with the same dimensions. What is the combined surface area of the new rectangular solid?
- 2. How much surface area has been lost?

For more practice problems go to page 879, and visit Math Practice at <a href="mailto:qpescience.com">qpescience.com</a>.

**Temperature** In addition to stirring and decreasing particle size, a third way to increase the rate at which most solids dissolve is to increase the temperature of the solvent. Think about making hot chocolate from a mix. You can make the sugar in the chocolate mix dissolve faster by putting it in hot water instead of cold water. Increasing the temperature of a solvent speeds up the movement of its particles. This increase causes more solvent particles to bump into the solute. As a result, solute particles break loose and dissolve faster.

**Controlling the Process** Think about how the three factors you just learned about affect the rate of dissolving. Can these factors combine to further increase the rate, or perhaps control the rate of dissolving? Each technique—stirring, crushing, and heating—is known to speed up the rate of dissolving by itself. However, when two or more techniques are combined, the rate of dissolving is even faster. Consider a sugar cube placed in cold water. You know that the sugar cube eventually will dissolve. You can predict that heating the water will increase the rate by some amount. You also can predict that heat and stirring will increase the rate further. Finally, you can predict that crushing the cube combined with heating and stirring will result in the fastest rate of dissolving. Knowing how much each technique affects the rate will allow you to control the rate of dissolving more precisely.

### section

# review

### **Summary**

#### What is a solution?

- A solution is a uniform mixture.
- A solution has the same composition, color, density, and taste throughout.

### **Solutes and Solvents**

• In a solution, the solute is the substance that is being dissolved; the solvent is the substance that is doing the dissolving.

#### **How Substances Dissolve**

• The process of dissolving happens at the surface and is aided by polarity and molecular movement.

#### **Rate of Dissolving**

• Stirring, surface area, and temperature affect the rate of dissolving.

### **Self Check**

- 1. List possible ways that phases of matter could combine to form a solution.
- 2. **Describe** how temperature affects the rate of dissolving.
- 3. **Describe** how the metal atoms in an alloy are mixed.
- **4. Think Critically** Amalgams, which sometimes are used in tooth fillings, are alloys of mercury with other metals. Is an amalgam a solution? Explain.

### **Applying Math**

- 5. Find Surface Area Calculate the surface area of a rectangular solid with dimensions  $\ell=2$  cm, w = 1 cm, and h = 0.5 cm.
- **6. Calculate Percent Increase** If the length of the rectangle in question 5 is increased by 10 percent, by how much will the surface area increase?

# Solubility and Concentration

# **Reading Guide**

# What You'll Learn

- Define the concept of solubility.
- Identify how to express the concentration of solutions.
- **List** and define three types of
- **Describe** the effects of pressure and temperature on the solubility of gases.

# Why It's Important

Solutions such as medicine and lemonade work and taste a particular way because of the specific solution concentrations.

### Review Vocabulary

substance: element or compound that cannot be broken down into simpler components

### **New Vocabulary**

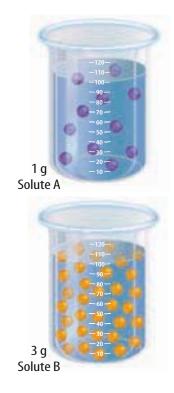
- solubility
- concentration
- saturated solution
- unsaturated solution
- supersaturated solution

### How much can dissolve?

You can stir several teaspoons of salt into water, and the salt will dissolve. However, if you continue adding salt, eventually the point is reached when no more salt dissolves and the excess salt sinks to the bottom of the glass. This indicates how soluble salt is in water. Solubility (sol yuh BIH luh tee) is the maximum amount of a solute that can be dissolved in a given amount of solvent at a given temperature.



**Comparing Solubilities** The amount of a solute that can dissolve in a solvent depends on the nature of these substances. **Figure 6** shows two beakers with the same volume of water and two different solutes. In one beaker, 1 g of solute A dissolves completely, but additional solute does not dissolve and falls to the bottom of the beaker. On the other hand, 1 g of solute B dissolves completely, and two more grams also dissolve before solute begins to fall to the bottom. You can conclude that substance B is more soluble than substance A, if the temperature of the water is the same in both beakers. **Table 1** shows how the solubility of several substances varies at 20°C. For solutes that are gases, the pressure also must be given.



**Figure 6** Substance B is more soluble in water than substance A is at the same temperature.

### **Table 1 Solubility of Substances** in Water at 20°C

III Water at 20 0		
Substance	Solubility in g/100 g of Water	
Solid Substances Salt (sodium chloride) Baking soda (sodium bicarbonate) Washing soda (sodium carbonate) Lye (sodium hydroxide) Sugar (sucrose)	35.9 9.6 21.4 109.0 203.9	
Gaseous Substances* Hydrogen Oxygen Carbon dioxide *at normal atmospheric pressure	0.00017 0.005 0.16	

### **Concentration**

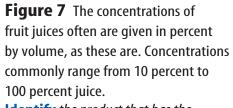
Suppose you add one teaspoon of lemon juice to a glass of water to make lemonade. Your friend adds four teaspoons of lemon juice to another glass of the same size. What is the difference between these two glasses of lemonade? The difference between the two drinks is the amount of water present compared to the amount of lemon juice. The concentration describes how much solute is present in a solution compared to the amount of solvent. A concentrated solution is one in which a large amount of solute is dissolved in the solvent. A dilute solution is one that has a small amount of solute in the solvent.

**Precise Concentrations** How much real fruit juice is there in one of those boxed fruit drinks? You can read the label to find out. Concentrated and dilute are not precise terms. Concentrations of solutions can be described precisely. One way is to state the percentage by volume of the solute. The percentage by volume of the juice in the bottled drink shown in Figure 7 is 10 percent. Adding 10 mL of

> juice to 90 mL of water makes 100 mL of this drink. Commonly, fruit-flavored drinks can have ten percent or less fruit juice. Generally, if two or more liquids are being mixed, the concentration is given in percentage by volume.







**Identify** the product that has the highest concentration.





# **Types of Solutions**

How much solute can dissolve in a given amount of solvent? That depends on a number of factors, including the solubility of the solute. Here you will examine the types of solutions based on the amount of a solute dissolved.

**Saturated Solutions** If you add 35 g of copper(II) sulfate, CuSO<sub>4</sub>, to 100 g of water at 20°C, only 32 g will dissolve. You have a saturated solution because no more copper(II) sulfate can dissolve. A **saturated solution** is a solution that contains all the solute it can hold at a given temperature. However, if you heat the mixture to a higher temperature, more copper(II) sulfate can dissolve. Generally, as the temperature of a liquid solvent increases, the amount of solid solute that can dissolve in it also increases. **Table 2** shows the amounts of a few solutes that can dissolve in 100 g of water at different temperatures to form saturated solutions. Some of these data also are shown on the accompanying graph.

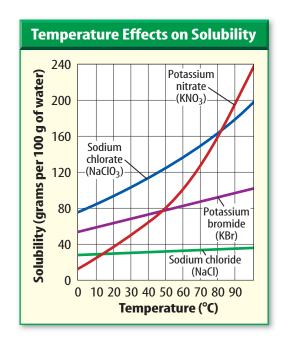
**Solubility Curves** Each line on the graph from **Table 2** is called a solubility curve for a particular substance. You can use a solubility curve to determine how much solute will dissolve at any temperature given on the graph. For example, about 78 g of KBr (potassium bromide) will form a saturated solution in 100 g of water at 47°C. How much NaCl (sodium chloride) will form a saturated solution with 100 g of water at the same temperature?

**Unsaturated Solutions** An unsaturated solution is any solution that can dissolve more solute at a given temperature. Each time a saturated solution is heated to a higher temperature, it generally becomes unsaturated. The term *unsaturated* isn't precise. If you look at **Table 2**, you'll see that at 20°C, 35.9 g of NaCl (sodium chloride) forms a saturated solution in 100 g of water. However, an unsaturated solution of NaCl could be any amount less than 35.9 g in 100 g of water at 20°C.

Reading Check
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What happens to a saturated solution if it is heated?

Table 2 Solubility of Compounds in g/100 g of Water			
Compound	0°C	20°C	100°C
Copper(II) sulfate	23.1	32.0	114
Potassium bromide	53.6	65.3	104
Potassium chloride	28.0	34.0	56.3
Potassium nitrate	13.9	31.6	245
Sodium chlorate	79.6	95.9	204
Sodium chloride	35.7	36.0	39.2
Sucrose (sugar)	179.2	203.9	487.2





### **Topic: Crystallization**

Visit **gpescience.com** for Web links to information about crystals and crystallization.

**Activity** Find instructions for a safe "do-it-yourself" home crystallization experiment. Grow the crystals as directed and share the results with the class.

Figure 8 A supersaturated solution is unstable. **Explain** why this is so.



A seed crystal of sodium acetate is added to a supersaturated solution of sodium acetate.

**Supersaturated Solutions** If you make a saturated solution of potassium nitrate at 100°C and then let it cool to 20°C, part of the solute comes out of solution. This is because the solvent cannot hold as much solute at the lower temperature. Most other saturated solutions behave in a similar way when cooled. However, if you cool a saturated solution of sodium acetate from 100°C to 20°C without disturbing it, no solute comes out. At this point, the solution is supersaturated. A supersaturated **solution** is one that contains more solute than a saturated solution at the same temperature. Supersaturated solutions are unstable. For example, if a seed crystal of sodium acetate is dropped into the supersaturated solution, excess sodium acetate crystallizes out, as shown in Figure 8.

**Solution Energy** As the supersaturated solution of sodium acetate crystallizes, the solution becomes hot. Energy is given off as the sodium acetate forms crystals. Some portable heat packs use crystallization from supersaturated solutions to produce heat. After crystallization, the heat pack can be reused by heating it to again dissolve all the solute.

Substances, such as ammonium nitrate, draw energy from their surroundings to dissolve. This is what happens when a cold pack is activated to treat minor injuries or to reduce swelling. When the inner bags of ammonium nitrate and water are broken, the ammonium nitrate draws energy from the water, which causes the temperature of the water to drop, which makes the the pack cool.



Why is energy given off between ions and water molecules?



**Excess solute immediately** crystallizes from solution.



The crystallization reaction draws solute from the solution.

# **Solubility of Gases**

When you shake an opened bottle of soda, it bubbles up and may squirt out. Shaking or pouring a solution of a gas in a liquid causes gas to come out of solution. Agitating the solution exposes more gas molecules to the surface, where they escape from the liquid.

**Pressure Effects** What might you do if you want to dissolve more gas in a liquid? One thing you

can do is increase the pressure of that gas over the liquid. Soft drinks are bottled under increased pressure. This increases the amount of carbon dioxide that dissolves in the liquid. When the pressure is released, the carbon dioxide bubbles out, as shown in Figure 9.

**Temperature Effects** Another way to increase the amount of gas that dissolves in a liquid is to cool the liquid. This is just the opposite of what you do to increase the speed at which most solids dissolve in a liquid. Imagine what happens to the carbon dioxide when a bottle of soft drink is opened. Even more carbon dioxide will bubble out of a soft drink as it gets warmer.





**Figure 9** Solutions of gases behave differently from those of solids or liquids. This soda is bottled under pressure to keep carbon dioxide in solution. When the bottle is opened, pressure is released and carbon dioxide bubbles out of solution.

# section

### **Summary**

### How much can dissolve?

 Solubility tells how much solute can dissolve in a solvent at a particular temperature.

#### **Concentration**

 A concentrated solution has a larger amount of dissolved solute. A dilute solution has a smaller amount of dissolved solute.

### **Types of Solutions**

- Saturated, unsaturated, and supersaturated solutions are defined by how much solute is dissolved.
- Solubility curves help predict how much solute can dissolve at a particular temperature.
- Some supersaturated solutions absorb or give off energy.

### **Solubility of Gases**

 Pressure and temperature affect gases in solution. High pressure and low temperature allow more gas to dissolve.

### **Self Check**

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- **1. Explain** Do all solutes dissolve to the same extent in the same solvent? How do you know?
- 2. Interpret from Table 2 the mass of sugar that would have to be dissolved in 100 g of water to form a saturated solution at 20°C.
- 3. **Determine** which solution is more concentrated: 17 g of solute X dissolved in 100 mL of water at 23°C or 26 g of solute Z dissolved in 100 mL of water at 23°C.
- **4. Identify** the type of solution you have if, at 35°C, the solute continues to dissolve as you add more.
- 5. Think Critically Explain how keeping a carbonated beverage capped helps keep it from going "flat."

### **Applying Math**

**6. Calculate Cost** By volume, orange drink is ten percent each of orange juice and corn syrup. A 1.5-L can of the drink costs \$0.95. A 1.5-L can of orange juice is \$1.49, and 1.5 L of corn syrup is \$1.69. Per serving, does it cost less to make your own orange drink or buy it?

# Acids, Bases, and Salts

### **Reading Guide**

# What You'll Learn

- Compare and contrast acids and bases and identify the characteristics they have.
- **Examine** some formulas and uses of common acids and bases.
- **Determine** how the processes of ionization and dissociation apply to acids and bases.

# Why It's Important

Acids and bases are found almost everywhere—from fruit juice and gastric juice to soaps.

### Review Vocabulary

electrolyte: compound that breaks apart in water, forming charged particles (ions) that can conduct electricity

### **New Vocabulary**

- acid
- indicator
- base

### **Figure 10** The acids in these common foods give each their distinctive sour taste.



### **Acids**

What comes to mind when you hear the word acid? Do you think of a substance that can burn your skin or even burn a hole through a piece of metal? Do you think about sour foods such as those shown in **Figure 10?** Although some acids can burn and are dangerous to handle, most acids in foods are safe to eat. What acids have in common, however, is that they contain at least one hydrogen atom that can be removed when the acid is dissolved in water.

**Properties of Acids** When an acid dissolves in water, some of the hydrogen is released as hydrogen ions, H<sup>+</sup>. An acid is a substance that produces hydrogen ions in a water solution. It is the ability to produce these ions that gives acids their characteristic properties. When an acid dissolves in water, H<sup>+</sup> ions interact with water molecules to form H<sub>3</sub>O<sup>+</sup> ions, which are called hydronium ions (hi DROH nee um • I ahnz).

Acids have several common properties. For one thing, all acids taste sour. The familiar, sour taste of many foods is due to acids. However, taste never should be used to test for the presence of acids. Some acids can damage tissue by producing painful burns. Acids are corrosive. Some acids react strongly with certain metals, eating away the metals and forming metallic compounds and hydrogen gas. Acids also react with indicators to produce predictable changes in color. An **indicator** is an organic compound that changes color in acids and bases. For example, the indicator litmus paper turns red in acid.

**Common Acids** Many foods contain acids. In addition to citric acid in citrus fruits, lactic acid is found in yogurt and buttermilk, and food, such as pickles, contain vinegar, also known as acetic acid. Your stomach uses acid to help digest your food. At least four acids (sulfuric, phosphoric, nitric, and hydrochloric) play roles in industrial applications.

# Reading Check Which four acids are important for industry?

Table 3 lists the names and formulas of a few acids, their uses, and some properties. Three acids are used to make fertilizers; most of the nitric acid and sulfuric acid and approximately 90 percent of phosphoric acid produced are used for this purpose. Many acids can burn, but sulfuric acid can burn by removing water from your skin as easily as it takes water from sugar, as shown in **Figure 11.** 



Figure 11 When sulfuric acid is added to sugar, the mixture foams, removing hydrogen and oxygen atoms as water and leaving airfilled carbon.

Table 3 Common Acids and Their Uses		
Name, Formula	Use	Other Information
<b>Acetic acid,</b> CH <sub>3</sub> COOH	Food preservation and preparation	When in solution with water, it is known as vinegar.
Acetylsalicylic acid, HOOC—C <sub>6</sub> H <sub>4</sub> —OOCCH <sub>3</sub>	Pain relief, fever relief, to reduce inflammation	Known as aspirin
Ascorbic acid, $H_2C_6H_6O_6$	Antioxidant, vitamin	Called vitamin C
Carbonic acid, H <sub>2</sub> CO <sub>3</sub>	Carbonated drinks	Involved in cave, stalactite, and stalagmite formation
<b>Hydrochloric acid,</b> HCl	Digestion as gastric juice in stomach, to clean steel in a process called pickling	Commonly called muriatic acid
Nitric acid, HNO <sub>3</sub>	To make fertilizers	Used to produce nitrogen fertilizers
<b>Phosphoric acid,</b> H <sub>3</sub> PO <sub>4</sub>	To make detergents, fertilizers, and soft drinks	Slightly sour but pleasant taste, detergents containing phosphates cause water pollution
<b>Sulfuric acid,</b> H <sub>2</sub> SO <sub>4</sub>	Car batteries, to manufacture fertilizers and other chemicals	Dehydrating agent, causes burns by removing water from cells



### **Observing Acid Relief**

**WARNING:** Do not eat antacid tablets.

### **Procedure**



- 1. Complete the safety form.
- 2. Add 150 mL of water to a 250-mL beaker.
- 3. Add three drops of 1*M* HCl and 12 drops of universal indicator.
- **4.** Observe the color of the solution.
- 5. Add an antacid tablet and observe for 15 min.

### **Analysis**

- 1. Describe any changes that took place in the solution.
- **2.** Explain why these changes occurred.

Figure 12 Bases commonly are found in many cleaning products used around the home. **Identify** the property of bases evident in soaps.

### **Bases**

You might not be as familiar with bases as you are with acids. Although you eat some foods that are acidic, you don't consume many bases. Some foods, such as egg whites, are slightly basic. Another example of basic materials is baking powder, which is found in some foods. Medicines, such as milk of magnesia and antacids, are basic, too. Still, you come in contact with many bases every day. Each time you wash your hands using soap, you are using a base. One characteristic of bases is that they feel slippery, like soapy water. Bases are important in many types of cleaning materials, as shown in **Figure 12.** Bases are important in industry, also. For example, sodium hydroxide is used in the paper industry to separate fibers of cellulose from wood pulp. The freed cellulose fibers are made into paper.

Bases can be defined in two ways. Any substance that forms hydroxide ions,  $OH^-$ , in a water solution is a **base**. In addition, a base is any substance that accepts H<sup>+</sup> from acids. The definitions are related, because the OH<sup>-</sup> ions produced by some bases do accept H<sup>+</sup> ions.



Reading Check What are the two definitions of a base?

**Properties of Bases** One way to think about bases is as the complements, or opposites, of acids. Although acids and bases share some common features, bases have their own characteristic properties. In the pure, undissolved state, many bases are crystalline solids. In solution, bases feel slippery and have a bitter taste. Like strong acids, strong bases are corrosive, and contact with skin can result in severe burns. Taste and touch never should be used to test for the presence of a base or an acid. Finally, like acids, bases react with indicators to produce changes in color. The indicator litmus turns blue in bases.



**Figure 13** Two applications of bases are shown here.



Aluminum hydroxide is a base used in water-treatment plants. Its sticky surface collects impurities, making them easier to filter from the water.



**Common Bases** You probably are familiar with many common bases because they are found in cleaning products used in the home. These and some other bases are shown in **Table 4**, which also includes their uses and some information about them. **Figure 13** shows two uses of bases that you might not be familiar with.

Table 4 Common Bases and Their Uses		
Name, Formula	Use	Other Information
Aluminum hydroxide, Al(OH) <sub>3</sub>	Color-fast fabrics, antacid, water purification as shown in <b>Figure 13</b>	Sticky gel that collects suspended clay and dirt particles on its surface
Calcium hydroxide, Ca(OH) <sub>2</sub>	Leather-making, mortar and plaster, to lessen acidity of soil	Called caustic lime
Magnesium hydroxide, Mg(OH) <sub>2</sub>	Laxative, antacid	Called milk of magnesia when in water
<b>Sodium hydroxide,</b> NaOH	To make soap, oven cleaner, drain cleaner, textiles, and paper	Called lye and caustic soda; generates heat (exothermic) when combined with water, reacts with metals to form hydrogen
Ammonia, NH <sub>3</sub>	Cleaners, fertilizer, to make rayon and nylon	Irritating odor that is damaging to nasal passages and lungs

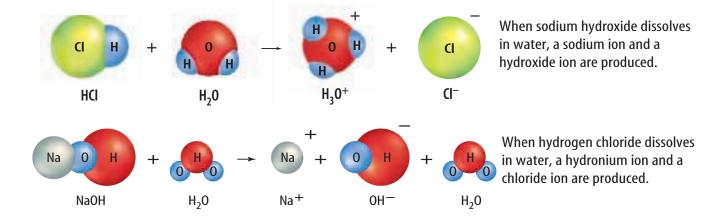


Figure 14 When acids and bases are dissolved in water, they produce ions. Acids produce hydronium ions in water. Bases produce hydroxide ions in water.



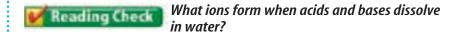
Acidic Stings Some ants add sting to their bite by injecting a solution of formic acid. In fact, formic acid was named for ants, which make up the genus Formica. Still, ants are considered tasty treats by many animals. For example, one woodpecker called a flicker has saliva that is basic enough to take the sting out of ants. Research the chemical formula and physical properties of formic acid.

### **Solutions of Acids and Bases**

Many of the products that rely on the chemistry of acids and bases are solutions, such as the cleaning products and food products mentioned previously. Because of its polarity, water is the main solvent in these cleaning products.

**Dissociation of Acids** You have learned that substances such as HCl, HNO<sub>3</sub>, and H<sub>2</sub>SO<sub>4</sub> are acids because of their ability to produce hydrogen ions (H<sup>+</sup>) in water. When an acid dissolves in water, the negative areas of nearby water molecules attract the positive hydrogen in the acid. The acid dissociates into ions and the hydrogen atom combines with a water molecule to form hydronium ions (H<sub>3</sub>O<sup>+</sup>). Dissociation is the process in which an ionic solid separates into its positive and negative ions. An acid can more accurately be described as a compound that produces hydronium ions when dissolved in water, as shown in **Figure 14.** 

**Dissociation of Bases** Compounds that can form hydroxide ions (OH-) in water are classified as bases. If you look at **Table 4,** you will find that most of the substances listed contain -OH in their formulas. When bases that contain -OH dissolve in water, the negative areas of nearby water molecules attract the positive ion in the base. The positive areas of nearby water molecules attract the -OH of the base. The base dissociates into a positive ion and a negative ion—a hydroxide ion (OH–). This process also is shown in **Figure 14.** Unlike in acid dissociation, water molecules do not combine with the ions formed from the base.



**Neutralization** Advertisements for antacids claim that these products neutralize the excess stomach acid that causes indigestion. Normally, gastric juice is acidic. Too much acid can produce discomfort. Antacids contain bases or other compounds containing sodium, calcium, magnesium, or aluminum that react with acids to lower acid concentration. Figure 15 shows what happens when you ingest an antacid tablet containing sodium bicarbonate, NaHCO<sub>3</sub>. The acid (HCl) is neutralized by the base (NaHCO<sub>3</sub>).

Neutralization is a chemical reaction between an acid and a base that takes place in a water solution. When HCl is neutralized by NaOH, hydronium ions from the acid combine with hydroxide ions from the base to produce water.

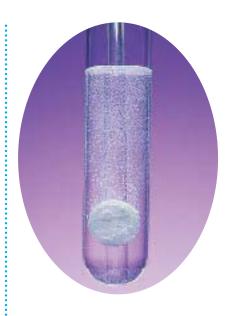
$$\mathrm{H_{3}O^{+}}(\mathit{aq}) + \mathrm{OH^{-}} \rightarrow 2\mathrm{H_{2}O}(\mathit{l})$$

**Acid-Base Reactions** The following general equation represents acid-base reactions in water. A few common salts are listed in **Table 5.** 

acid + base 
$$\rightarrow$$
 salt + water

**Salt Formation** The acid-base equation accounts for only half of the ions in the solution. The remaining ions react to form a salt. A salt is a compound formed when the negative ions from an acid combine with the positive ions from a base. In the reaction between HCl and NaOH, the salt formed in water solution is sodium chloride.

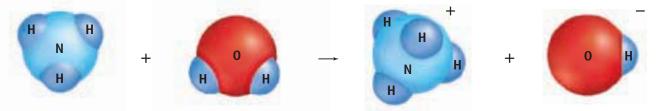
$$Na^+(aq) + Cl^-(aq) \rightarrow NaCl(aq)$$



**Figure 15** An antacid tablet reacts in your stomach much as it does in this dilute HCI. Many antacid tablets are made to be chewed before they are swallowed. **Explain** how chewing the tablet would affect the rate of the reaction.

Table 5 Some Common Salts and Their Uses			
Name, Formula	Common Name	Uses	
<b>Sodium chloride,</b> NaCl	Salt	Food, manufacture of chemicals	
<b>Sodium hydrogen carbonate,</b> NaHCO <sub>3</sub>	Sodium bicarbonate, baking soda	, Food, antacids	
Calcium carbonate, CaCO <sub>3</sub>	Calcite, chalk	Manufacture of paint and rubber tires	

**Figure 16** Ammonia reacts with water to produce some hydroxide ions; therefore, it is a base.





#### **Topic: Cleaner Chemistry**

Visit gpescience.com for Web links to information about the dangers of mixing ammonia cleaners with chlorine or hydrochloric acid cleaners.

**Activity** Visit the cleaning products and laundry sections of the grocery store. Read the labels on several products. Make a list of products that include warnings on the labels and those that do not. Share your findings with the class.

**An Exception** Ammonia is a base that does not contain -OH. In a water solution, dissociation takes place when the ammonia molecule attracts a hydrogen ion from a water molecule, forming an ammonium ion (NH<sub>4</sub>+). This leaves a hydroxide ion (OH<sup>-</sup>), as shown in **Figure 16.** 

Reading Checks How does ammonia react in a water solution?

Ammonia is a common household cleaner. However, products containing ammonia never should be used with other cleaners that contain chlorine or sodium hypochlorite, such as some bathroom toilet-bowl cleaners and bleach. A reaction between sodium hypochlorite and ammonia produces the toxic gases hydrazine and chloramine. Breathing these gases can severely damage lung tissues and cause death.

The reactions of acids and bases are important to the chemistry of living systems, the environment, and many industrial processes.

# section

# review

#### Summary

#### Acids

- Acids, when dissolved in water, release H<sup>+</sup>, which forms hydronium ions  $(H_2O^+)$ .
- Acids are sour tasting, corrosive, and reactive with indicators.

#### **Bases**

- Bases, when dissolved in water, form OH<sup>-</sup>.
- Bases are slippery, have a bitter taste, are corrosive, and are reactive with indicators.

#### **Solutions of Acids and Bases**

- The polar nature of water allows acids and bases to dissolve in water.
- Dissociation is the separation of substances, such as acids and bases, into ions in water.

#### **Self Check**

- 1. **Identify** three important acids and three important bases and describe their uses.
- 2. Describe an indicator.
- **3. Predict** what metallic compound forms when sulfuric acid reacts with magnesium metal.
- 4. Infer If an acid donates H<sup>+</sup> and a base produces OH<sup>-</sup>, what compound is likely to be produced when acids react with bases?
- **5. Think Critically** Vinegar contains acetic acid, CH<sub>2</sub>COOH. What salt is formed if acetic acid reacts with sodium hydroxide, NaOH?

#### **Applying Math**

**6. Calculate** the molecular weight of acetylsalicylic acid,  $C_0H_8O_4$ .



# Strength of Acids and Bases

## **Reading Guide**

#### What You'll Learn

- Determine what is responsible for the strength of an acid or a base.
- Compare and contrast strength and concentration.
- Examine the relationship between pH and acid or base strength.
- Examine electrical conductivity.

# Why It's Important

Understanding the strength of acids and bases helps you use them safely.

#### Review Vocabulary

**acid strength:** the ability of an acid to dissociate completely

#### **New Vocabulary**

- strong acid
- weak acid
- strong base
- weak base
- pH

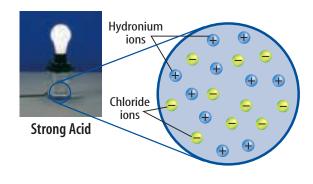
## **Strong and Weak Acids and Bases**

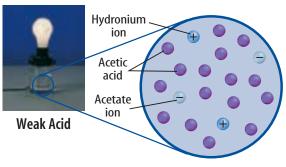
Some acids must be handled with great care. For example, sulfuric acid found in car batteries can burn your skin, yet you drink acids such as citric acid in orange juice. Obviously, some acids are stronger than others. One measure of acid strength is the ability to dissociate in solution.

The strength of an acid or base depends on how many acid or base particles dissociate into ions in water. When a **strong acid** dissolves in water, almost 100 percent of the acid molecules dissociate into ions. HCl, HNO<sub>3</sub>, and H<sub>2</sub>SO<sub>4</sub> are examples of strong acids. When a **weak acid** dissolves in water, only a small fraction of the acid molecules dissociates into ions. Acetic acid and carbonic acid are examples of weak acids.

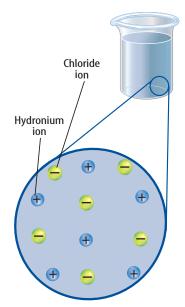
Ions in solution can conduct an electric current are called electrolytes. The more ions a solution contains, the more current it can conduct. The ability of a solution to conduct a current can be demonstrated using a lightbulb connected to a battery with leads placed in the solution, as shown in **Figure 17.** The strong acid solution conducts more current. The weak acid solution does not conduct as much current as a strong acid solution.

**Figure 17** HCI is a strong acid. The bulb burns brightly. Acetic acid is a weak acid. The bulb is dimmer.

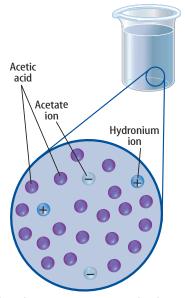




**Figure 18** You can have a dilute solution of a strong acid and a concentrated solution of a weak acid.



This shows a dilute solution of HCl.



This shows a concentrated solution of acetic acid.

**Strong and Weak Acids** Equations describing dissociation are written in two ways. In strong acids, such as HCl, nearly all the acid dissociates. This is shown by writing the equation using a single arrow pointing toward the ions that are formed.

$$\mathrm{HCl}(g) \, + \, \mathrm{H_2O}(l) \longrightarrow \mathrm{H_3O^+}(aq) \, + \, \mathrm{Cl^-}(aq)$$

Almost 100 percent of the particles in solution are H<sub>3</sub>O<sup>+</sup> and Cl<sup>-</sup> ions, and only a negligible number of HCl molecules are present.

Equations describing the dissociation of weak acids, such as acetic acid, are written using double arrows pointing in opposite directions. This means that only some of the CH<sub>3</sub>COOH dissociates and the reaction does not go to completion.

$$\mathrm{CH_{3}COOH}(\mathit{aq}) + \mathrm{H_{2}O}(\mathit{l}) \Longleftrightarrow \mathrm{H_{3}O^{+}}(\mathit{aq}) + \mathrm{CH_{3}COO^{-}}(\mathit{aq})$$

In an acetic acid solution, most of the particles are CH<sub>3</sub>COOH molecules, and only a few CH<sub>3</sub>COO<sup>-</sup> and H<sup>+</sup> ions are in solution.

**Strong and Weak Bases** Remember that many bases are ionic compounds that dissociate to produce ions when they dissolve. A **strong base** dissociates completely in solution. The following equation shows the dissociation of sodium hydroxide, a strong base.

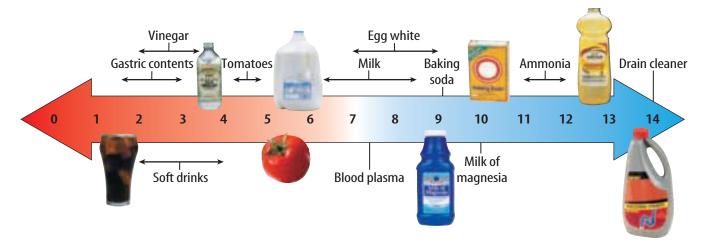
$$NaOH(s) + H_2O(l) \rightarrow Na^+(aq) + OH^-(aq)$$

The dissociation of ammonia, which is a weak base, is shown using double arrows to indicate that not all the ammonia dissociates. A **weak base** is one that does not dissociate completely.

$$NH_3(aq) + H_2O(l) \Longrightarrow NH_4^+(aq) + OH^-(aq)$$

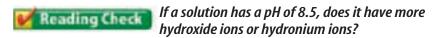
Because ammonia produces only a few ions and most of the ammonia remains in the form of NH<sub>3</sub>, ammonia is a weak base.

**Strength and Concentration** Sometimes, when talking about acids and bases, the terms *strength* and *concentration* can be confused. The terms *strong* and *weak* are used to classify acids and bases. The terms refer to the ease with which an acid or base dissociates in solution. *Strong* acids and bases dissociate completely; *weak* acids and bases dissociate only partially. In contrast, the terms *dilute* and *concentrated* are used to indicate the concentration of a solution, which is the amount of acid or base dissolved in the solution. It is possible to have dilute solutions of strong acids and bases and concentrated solutions of weak acids and bases, as shown in **Figure 18**.



### pH of a Solution

If you have a swimming pool or keep tropical fish, you know that the pH of the water must be controlled. Also, many shampoo products claim to control pH, making them suitable for your type of hair. The **pH** of a solution is a measure of the concentration of H<sup>+</sup> ions in it. The greater the H<sup>+</sup> concentration is, the lower the pH is and the more acidic the solution is. The pH measures how acidic or basic a solution is. To indicate pH, a scale ranging from 0 to 14 has been devised, as shown in **Figure 19.** 



As the scale shows, solutions with a pH lower than 7 are described as acidic, and the lower the value is, the more acidic the solution is. Solutions with a pH greater than 7 are basic, and the higher the pH is, the more basic the solution is. A solution with a pH of exactly 7 indicates that the concentrations of H<sup>+</sup> ions and OH<sup>-</sup> ions are equal. These solutions are considered neutral. Pure water at 25°C has a pH of 7.

One way to determine pH is by using indicator paper. This paper undergoes a color change in the presence of  $H_3O^+$  ions and  $OH^-$  ions in solution. The final color of the pH paper is matched with colors in a chart to find the pH, as shown in **Figure 20.** Is this an accurate way to determine pH?

An instrument called a pH meter is another tool to determine the pH of a solution. This meter is operated

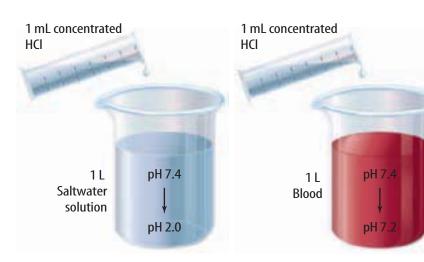
by immersing the electrode in the solution to be tested and reading the dial. Small, battery-operated pH meters with digital readouts, as shown in **Figure 20**, are precise and convenient for use outside the laboratory when testing the pH of soils and streams.

**Figure 19** The pH scale helps classify solutions as acidic or basic.

**Figure 20** The pH of a sample can be measured in several ways. Indicator paper gives an approximate value quickly, however, a pH meter is quick and more precise.







**Figure 21** This experiment shows how well blood plasma acts as a buffer. Adding 1 mL of concentrated HCl to 1 L of saltwater solution changes the pH from 7.4 to 2.0. Adding the same amount of concentrated HCl to 1 L of blood plasma changes the pH from 7.4 to 7.2.

# **Blood pH**



Your blood circulates

throughout your body carrying oxygen, removing carbon dioxide, and absorbing nutrients from food that you have eaten. In order to carry out its many functions properly, the pH of blood must remain between 7.0 and 7.8. The main reason for this is that

some enzymes cannot work outside this pH range. An enzyme is a protein molecule that acts as a catalyst for many reactions in the body. Yet you can eat foods that are acidic without changing the pH of your blood. How can this be? The answer is that your blood contains compounds called buffers that enable small amounts of acids or bases to be absorbed without harmful effects.

Buffers are solutions containing ions that react with additional acids or bases to minimize their effects on pH. One buffer system in blood involves bicarbonate ions,  $HCO_3^-$ . Because of these buffer systems, small amounts of even concentrated acid will not change pH much, as shown in **Figure 21.** Buffers help keep your blood close to a nearly constant pH of 7.4.



What are buffers and how are they important for health?

# section

# 4

## гечіеш

#### **Summary**

#### **Strong and Weak Acids and Bases**

- When strong acids dissolve in water, nearly all the acid particles dissociate into ions. When weak acids dissolve in water, few particles dissociate.
- When strong bases dissolve in water, nearly all base particles dissociate. When weak bases dissove, only a few particles dissociate.
- lons in solution can conduct electricity.
- Strength refers to the ability of an acid or base to dissociate in water; concentration refers to how much acid or base is in solution.

#### pH of a Solution

- pH describes a substance as acidic or basic.
- Buffers are substances that minimize the effects of an acid or base on pH.

#### **Self Check**

- 1. **Describe** what determines the strength of an acid. A base?
- **2. Explain** how to make a dilute solution of a strong acid.
- 3. Explain how electricity can be conducted by solutions.
- **4. Describe** pH values of 9.1, 1.2, and 5.7 as basic, acidic, or very acidic.
- **5. Think Critically** The proper pH range for a swimming pool is between 7.2 and 7.8. Some pools use two substances, NaHCO<sub>3</sub> and HCl, to maintain this range. How would you adjust the pH if you found it was 8.2? 6.9?

#### **Applying Math**

**6. Use Equations** To determine the difference in acid strength, calculate  $10^n$ , where n = difference between pHs. How much more acidic is a solution of pH 2.4 than a solution of pH 4.4?



# Determining Acidity

The science of acids and bases is not practiced only in high-tech laboratories by scientists. You can investigate the acidic concentrations of things in your own home using a simple homemade indicator solution.

### Real-World Problem –

How can you tell if a substance is a strong or weak acid?

#### Goal

■ **Determine** the relative concentrations of common acidic substances.

#### **Materials**

homemade cabbage indicator (indicates both acids and bases)

grease pencil or masking tape

coffee filter waxed paper teaspoons (3)

alum cream of tartar fruit preservative

#### **Safety Precautions**



#### Procedure

- 1. Complete the safety form.
- 2. Use the grease pencil or masking tape and a pencil to label three areas on the waxed paper *alum, cream of tartar,* and *fruit preservative*. These areas should be about 8 cm apart.
- **3.** Place approximately  $\frac{1}{2}$  teaspoon of each of the three powders on the waxed paper where labeled. Use a separate teaspoon for each substance.

- **4.** Cut three strips from the coffee filter, about 1 cm wide by 8 cm long.
- Dip the end of one of the strips into the cabbage indicator solution, then lay the wet end on top of the alum.
- **6.** Wet a second strip and lay it in on top of the cream of tartar.
- **7.** Wet the third strip and lay on top of the fruit preservative.
- **8.** Wait 5 min, then check the indicator strips and record your observations.

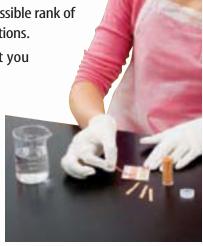
# Conclude and Apply-

**1. Determine** if all three substances were acids. Did the indicator strips turn a similar color?

**2. Explain** why each substance produced a different color.

**3. Propose** a possible rank of the concentrations.

4. Predict what you would have observed if you used sodium hydroxide instead of alum.



# Communicating Your Data

Compare your results with other groups in the class. Discuss any differences in the results you obtained.



# **Saturated S%lutions**

#### Goal

Observe the effects of temperature on the amount of solute that dissolves.

#### **Materials**

distilled water at room
temperature
large test tubes
Celsius thermometer
table sugar
copper wire stirrer, bent
into a spiral
test-tube holder
graduated cylinder (25-mL)
beaker (250-mL) with
150 mL of water
electric hot plate
test-tube rack
ring stand

#### **Safety Precautions**



WARNING: Do NOT touch the test tubes or hot-plate surface when hot plate is turned on or cooling down. When heating a solution in a test tube, keep it pointed away from yourself and others. Do NOT remove goggles until cleanup, including washing hands, is completed.

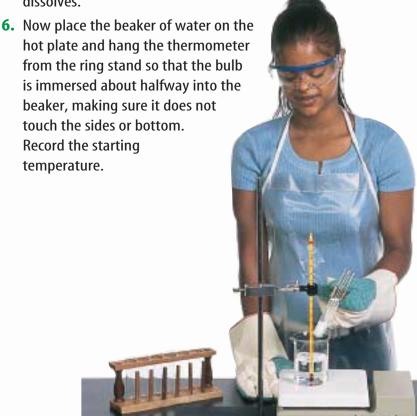
#### Real-World Problem

Two major factors to consider when you are dissolving a solute in water are temperature and the ratio of solute to solvent. What happens to a solution as the temperature changes? How does solubility change as temperature is increased? To be able to draw conclusions about the effect of temperature, you must keep other variables constant. For example, you must be sure to stir each solution in a similar manner.

#### Procedure

- 1. Complete the safety form.
- 2. Place 20 mL of distilled water in a test tube. Add 30 g of sugar.
- 3. Stir. Does the sugar dissolve?
- **4.** If it dissolves completely, add another 5 g of sugar to the test tube. Does it dissolve?

**5.** Continue adding 5-g amounts of sugar until no more sugar dissolves.



191 \* \* 10

# Using Scientific Methods

- **7.** Using a test-tube holder, place the test tube into the water.
- **8.** Gradually increase the temperature of the hot plate while stirring the solution in the test tube, until all the sugar dissolves.
- **9.** Note the temperature at which this happens.
- **10.** Add another 5 g of sugar and continue. Note the temperature at which this additional sugar dissolves.
- 11. Continue in this manner until you have at least four data points. Note the total amount of sugar that has dissolved. Record your data in the data table.



# Analyze Your Data

- 1. **Graph** your results using a line graph. Plot grams of solute per 20 g of water on the y-axis and plot temperature on the x-axis.
- **2. Interpret Data** Using your graph, estimate the solubility of sugar at 100°C and at 0°C, the boiling and freezing point of water, respectively.

Dissolving Sugar in Water	
Temperature	Total Grams of Sugar Dissolved
Do not write in this book.	

# Conclude and Apply

- **1. Explain** how the saturation change as the temperature was increased.
- **2. Compare** your results with the data in **Table 2.**



**Compare** your results with those of other groups and discuss any differences noted. Why might these differences have occurred? For more help, refer to the Science Skill Handbook.

TIME

SCIENCE AND SOCIETY

SCIENCE ISSUES THAT AFFECT YOU!

# Acid Rain

Protecting Earth from the Damaging Effects of Chemically Loaded Precipitation

cid precipitation is rain, snow, or sleet that is more acidic than unpolluted precipitation. It's caused by the burning of fossil fuels, such as coal, oil, and natural gas. In the United States, most gasoline and electricity come from fossil fuels. People burn fossil fuels each time they drive a car, heat a building, or turn on a light.

Normally, raindrops pick up particles and natural chemicals in the air. When rain falls, it mixes with the carbon dioxide in the atmosphere, giving clean rain a slightly acidic pH of 5.6. Then, natural chemicals found in the air and soil balance out the acidity, giving most lakes and streams a pH between 6.0 and 8.0. But when pollutants are introduced, these natural bases are not strong enough to neutralize these solutions. Wind can carry this acidic moisture for hundreds of miles before it falls to Earth as acid rain.

#### **Eating Away at History**

Like all acids, acid rain can corrode, or eat away at, substances. Many historical monuments, such as the Mayan temples in Mexico and the Parthenon in Greece, have been slowly but steadily damaged by acid rain. This kind of damage can be fixed, though it costs billions of dollars to ensure that ancient monuments and buildings are not destroyed.

#### **Some Solutions**

In some countries, high acid levels in lakes and streams have been lowered by adding lime to the water. Lime, a natural base, balances out the damaging chemicals. In the United States, all new cars must have catalytic converters, which help reduce the amount of exhaust pollution that vehicles give off.

You also can make a difference. Turning off the lights when you are not using them means a power plant does not have to produce as much electricity. By carpooling, using public transportation, and walking, there is less pollution from cars. The results of all these individual actions can make a huge difference in preserving our environment.



**List** Go to a local park or forest. List any effects of acid rain that you see. Make a list of the things you do that use energy or cause pollution. Think about what your family can do to reduce pollution and save energy. Share your list with an adult.

TIME
For more information, visit gpescience.com

#### **Reviewing Main Ideas**

#### **Section 1** How Solutions Form

- **1.** A solution is a mixture that has the same composition, color, density, and taste throughout.
- **2.** The substance being dissolved is called a solute, and the substance that does the dissolving is called a solvent.
- **3.** The rate of dissolving can be increased by stirring, increasing surface area, or increasing temperature.
- **4.** Under similar conditions, small particles of solute dissolve faster than large particles.

#### Section 2 **Solubility and Concentration**

- **1.** Some compounds are more soluble than others, and this can be measured.
- **2.** Concentrated and dilute are not precise terms used to describe concentrations of solutions.
- **3.** Concentrations can be expressed as percent by volume.
- **4.** An unsaturated solution can dissolve more solute, while a saturated solution, such as this

tea, cannot. A supersaturated solution is made by raising the temperature of a saturated solution and adding more solute. If it is cooled carefully, the supersaturated solution will retain the dissolved solute.



#### Section 3 Acids, Bases, and Salts

- **1.** An acid is a substance that produces hydrogen ions, H<sup>+</sup>, in solution. A base produces hydroxide ions, OH<sup>-</sup>, in solution.
- 2. Most foods can be classified as acidic or basic. Properties of acids and bases are due, in part, to the presence of the H<sup>+</sup> and OH<sup>-</sup> ions.



- **3.** Salts form when negative ions from an acid combine with positive ions from a base.
- **4.** Dissociation is the process where an ionic solid separates into its positive and negative ions.

#### Section 4 **Strength of Acids and Bases**

- 1. The strength of an acid or base is determined by how completely it forms ions when it is in solution.
- 2. Strength and concentration are not the same thing. Concentration involves the relative amounts of solvent and solute in a solution, whereas strength is related to the extent to which a substance dissociates.

FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review the characteristics of solutions, acids, and bases.

#### **Using Vocabulary**

- acid p.764
  aqueous solution p.751
  base p.766
  concentration p.760
  indicator p.764
  pH p.773
  saturated solution p.761
  solubility p.759
  solute p.751
- solution p.752 solvent p.751 strong acid p.771 strong base p.772 supersaturated solution p.762 unsaturated solution p.761 weak acid p.771

weak base p. 772

Fill in the vocabulary word(s) that correctly completes each sentence.

- **1.** In lemonade, sugar is the \_\_\_\_\_ and water is the \_\_\_\_\_
- **2.** A(n) \_\_\_\_\_ is a substance that produces hydrogen ions,  $H^+$ , in solution.
- **3.** Adding a seed crystal may cause solute to crystallize from a(n) \_\_\_\_\_.
- **4.** A(n) \_\_\_\_\_ produces hydroxide ions, OH \_, in solution.
- **5.** If more of substance B dissolves in water than substance A, then substance B has a higher than substance A.
- **6.** When a(n) \_\_\_\_\_\_ dissolves in water, nearly all the acid molecules dissociate into ions.
- **7.** The measure of the concentration of H<sup>+</sup> ions in solution is called the \_\_\_\_\_.
- **8.** A solution in which water is the solvent is called a(n) \_\_\_\_\_ solution.

#### **Checking Concepts**

Choose the word or phrase that best answers the question.

- **9.** What term is **NOT** appropriate to use when describing solutions?
  - A) gaseous
- c) liquid
- **B)** heterogeneous
- **D)** solid

- **10.** What is another name for sodium hydroxide (NaOH)?
  - A) ammonia
- **C)** lye
- B) caustic lime
- **D)** milk of magnesia
- **11.** When iodine is dissolved in alcohol, what term is used to describe the alcohol?
  - **A)** alloy
- **c)** solution
- **B)** solvent
- **D)** solute
- **12.** What word is used to describe a solution that is 85 percent copper and 15 percent tin?
  - **A)** alloy
- c) saturated
- **B)** solvent
- **D**) solute
- **13.** What is a common name for hydrochloric acid?
  - **A)** battery acid
- c) muriatic acid
- **B)** citric acid
- **D)** vinegar
- **14.** Which acid ionizes only partially in water?
  - A) HCl
- C)  $HNO_3$
- B)  $H_2SO_4$
- **D)** CH<sub>3</sub>COOH
- **15.** Carrots have a pH of 5.0. How would you describe them?
  - A) acidic
- c) an indicator
- **B)** basic
- **D)** neutral
- **16.** What is the pH of pure water at 25°C?
  - **A)** 0

**c)** 7

- **B)** 5
- **D)** 14
- **17.** What can you increase to make a gas more soluble in a liquid?
  - **A)** particle size
- **c)** stirring
- **B)** pressure
- **D)** temperature
- **18.** If a solute crystallizes out of a solution when a seed crystal is added, what kind of solution is it?
  - **A)** dilute
- **C)** supersaturated
- **B)** saturated
- **D)** unsaturated

#### Interpreting Graphics

Use the table below to answer question 19.

19. Explain which substance listed in the table would be most effective for neutralizing battery acid.

pH Readings		
Substance	рН	
Battery acid	1.5	
Lemon juice	2.5	
Apple	3	
Milk	6.7	
Seawater	8.5	
Ammonia	12	

Use the table below to answer question 20.

Limits of Solubility		
Compound	Type of Solution	Solubility in 100 g Water at 20°C
CuSO <sub>4</sub>		32.0 g
KCI	Do not write	38.0 g
KNO <sub>3</sub>	in this book.	31.6 g
NaClO <sub>3</sub>		45.8 g

**20.** Identify Using the data in Table 2, complete the table. Use the terms saturated, unsaturated, and supersaturated to describe the type of solution.

#### **Thinking Critically**

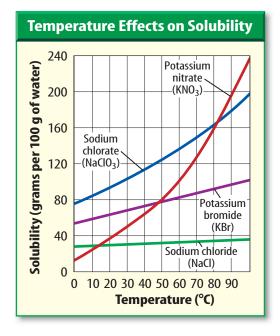
- **21. Describe** what happens to hydrogen chloride, HCl, when it is dissolved in water to form hydrochloric acid.
- **22.** Explain why ammonia is considered a base, even though it contains no hydroxide ions. Is it a strong or weak base?
- **23.** Explain why a concentrated acid is not necessarily a strong acid.
- **24.** Compare and Contrast How would the pH of a dilute solution of HCl compare with the pH of a concentrated solution of the same acid?

**25.** Explain why the statement, "Water is the solvent in a solution," is not always true.

#### **Applying Math**

**26.** Use Proportions To make an indicator solution, a student mixes 3 mL of a concentrated solution with 97 mL of water. How much concentrate is needed to make 3 L of the indicator?

Use the graph below to answer question 27.



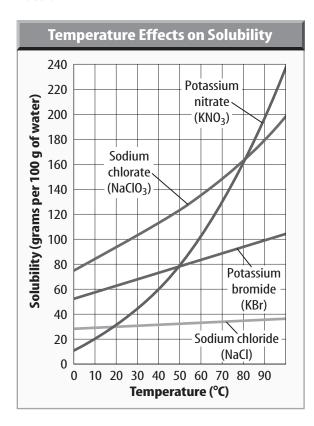
- **27. Interpret Data** Determine the temperature at which a solution of 80 g of potassium nitrate (KNO<sub>3</sub>) in 100 mL of water is saturated.
- **28.** Measure in SI You dissolve 153 g of potassium nitrate in enough water to make 1 L of solution. Then, you use a graduated cylinder to measure 80 mL of solution. What mass of potassium nitrate is in the 80-mL sample?
- **29.** Use Numbers How would you make a 25-percent solution by volume of an apple-juice drink?

# Standardized Test Practice chapter

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### Multiple Choice

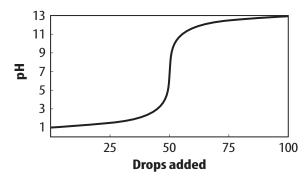
The graph below shows the solubility of various salts in water.



- 1. Which compound will make a saturated solution when added to 100 g of water?
  - **A.** 20 g NaCl if the water is 50°C
  - **B.** 60 g of KNO<sub>3</sub> if the water is 100°C
  - **c.** 80 g NaClO<sub>3</sub> if the water is 30°C
  - **D.** 100 g KBr if the water is 90°C

- 2. A label on a flask reads 130 g KNO<sub>3</sub>/100 g of water. A thermometer reading shows a room temperature of 23°C. No crystals are seen on the bottom of the flask. How is this solution best described?
  - **A.** concentrated
  - **B.** dilute
  - **C.** saturated
  - **D.** supersaturated
- **3.** What allows you to eat acidic foods without changing your blood pH?
  - A. blood plasma
  - **B.** buffers
  - C. enzymes
  - **D.** protein molecules
- **4.** The following graph is a titration curve. The data indicate the changes that happened to the solution as drops of a strong base were added.

#### Acids, Bases, and Salts



At the instant of neutralization, what is in the beaker (besides water)?

- **A.** acid only
- **B.** base only
- **c.** salt only
- **D.** equal amounts of each

- **5.** Which chemical formula below describes a hydronium ion?
  - **A.**  $H_3O^+$
  - **B.** OH<sup>-</sup>
  - c. COOH
  - **D.**  $H_2O$

#### **Gridded Response**

- **6.** The solubility of potassium chloride in water is 34 g per 100 g of water at 20°C. A warm solution containing 100 g of potassium chloride in 200 g of water is cooled to 20°C. How many grams of potassium chloride will come out of solution?
- 7. When the pH of a solution drops from 3.0 to 1.0, the hydronium ion concentration increases by a factor of 100 fold from 0.0010. What is the concentration at pH = 1.0?

#### Short Response

**8.** The drawing below shows carbon dioxide gas dissolved in water.





What are two ways you could make more gas dissolve in the water?

**9.** Name the salt that is produced by each of the following acid-base pairs.  $HCl + NaOH; HNO_3 + KOH;$  $H_2SO_4 + Ca(OH)_2$ 

#### **Extended Response**

10. One of the solutions has a pH of 10, the other pH of 12. In one beaker, the bulb glows more brightly than does the other.





Explain why the bulbs glow with different intensities. Use the words strong and weak in your answer.

- **11.** You are given a clear water solution containing potassium nitrate. How could you determine whether the solution is unsaturated, saturated, or supersaturated?
- **12.** Explain why a weak acid in solution has a higher pH than a strong acid of the same concentration.

#### **Test-Taking Tip**

**Answer Bubbles** Double-check that you are filling in the correct answer bubble for the question number you are working on.

# chapter

# 25

#### BIG (Idea

Protons and neutrons are held together in a nucleus by the strong nuclear force.

#### 25.1 Radioactivity

MAIN (Idea The repulsive electrical force between protons causes some nuclei to be unstable.

#### **25.2 Nuclear Decay**

MAIN (Idea Unstable nuclei can emit particles and energy when they decay.

# 25.3 Detecting Radioactivity

MAIN (Idea Nuclear radiation produces charged particles in matter that can be detected.

#### 25.4 Nuclear Reactions

MAIN (Idea Nuclear fission splits nuclei apart and nuclear fusion joins nuclei together.

#### Planet Power

Although less than one-billionth of the energy emitted by the Sun falls on Earth, this energy powers the entire planet. Solar energy is produced inside the Sun by nuclear fusion—a nuclear reaction in which atomic nuclei are joined together.

#### **Science Journal**

In your Science Journal, write a paragraph describing your impressions of the Sun.

# **Nuclear Changes**

# **Start-Up Activities**



#### The Size of a Nucleus

Do you realize you are made up mostly of empty space? Your body is made of atoms, and atoms are made of electrons whizzing around a small nucleus of protons and neutrons. The size of an atom is the size of the space in which the electrons move around the nucleus. In this lab, you'll find out how the size of an atom compares with the size of a nucleus.





- 1. Complete the safety form.
- **2.** Pour several grains of sugar onto a sheet of dark paper.
- Choose one of the grains of sugar to represent the nucleus of an atom. Tape this grain to the center of the sheet of paper.
- **4.** Place the sheet of paper in a large open space.
- 5. Use a meterstick to measure a distance of 10 m from the sugar grain. This distance represents the radius of the electron cloud around an atom.
- 6. Think Critically In your Science Journal, compare the size of an atom to the size of a nucleus. If an electron is much smaller than a nucleus, explain why an atom contains mostly empty space.

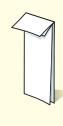


Radioactivity and Nuclear Reactions Make the following Foldable to help you understand radioactivity and nuclear reactions.

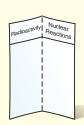




5TEP 2 Fold paper down
2.5 cm from the
top. (Hint: From
the tip of your
index finger to
your middle
knuckle is about
2.5 cm.)



Open and draw lines along the 2.5-cm fold. Label as shown.



Summarize in a Table As you read the chapter, write what you learn about radioactivity in the left column and what you learn about nuclear reactions in the right column.



Preview this chapter's content and activities at qpescience.com

# Radioactivity

## **Reading Guide**

#### What You'll Learn

- Describe the structure of an atom and its nucleus.
- **Explain** what radioactivity is.
- Compare and contrast properties of radioactive and stable nuclei.
- Discuss the discovery of radioactivity.

# Why It's Important

Radioactivity is everywhere because every element on the periodic table has some atomic nuclei that are radioactive.

#### Review Vocabulary

**long-range force:** a force that becomes weaker with distance, but never vanishes

#### **New Vocabulary**

- strong force
- radioactivity

cles. So rocks,

Figure 1 The size of a nucleus What to

in an atom can be compared to a marble sitting in the middle of an empty football stadium.



Every second you are being bombarded by energetic particles. Some of these particles come from unstable atoms in soil, rocks, and the atmosphere. What types of atoms are unstable? What type of particles do unstable atoms emit? The answers to these questions begin with the nucleus of an atom.

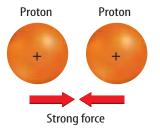
Recall that atoms are composed of protons, neutrons, and electrons. The nucleus of an atom contains the protons, which have a positive charge, and neutrons, which have no electric charge. The total amount of charge in a nucleus is determined by the number of protons, which also is called the atomic number. You might remember that an electron has a charge that is equal but opposite to a proton's charge. Atoms usually contain the same number of protons as electrons. Negatively charged electrons are electrically attracted to the positively charged nucleus and swarm around it.

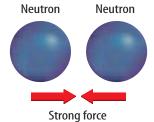
**Protons and Neutrons in the Nucleus** Protons and neutrons are packed together tightly in a nucleus. The region outside the nucleus in which the electrons are located is large compared to the size of the nucleus. As **Figure 1** shows, the

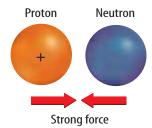
nucleus occupies only a tiny fraction of the space in the atom. If an atom were enlarged so that it was 1 km in diameter, its nucleus would have a diameter of only a few centimeters. But the nucleus contains almost all the mass of the atom, because the mass of one proton or neutron is almost 2,000 times greater than the mass of an electron.



**Figure 2** The particles in the nucleus are attracted to each other by the strong force.



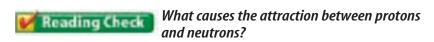




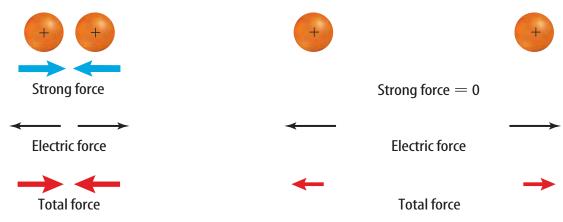
# **The Strong Force**

How do you suppose protons and neutrons are held together so tightly in the nucleus? Positive electric charges repel each other, so why don't the protons in a nucleus push each other away? Another force, called the **strong force**, causes protons and neutrons to be attracted to each other, as shown in **Figure 2.** 

The strong force is one of the four basic forces in nature and is about 100 times stronger than the electric force. The attractive forces between all the protons and neutrons in a nucleus keep the nucleus together. However, protons and neutrons have to be close together, like they are in the nucleus, to be attracted by the strong force. The strong force is a short-range force that quickly becomes extremely weak as protons and neutrons get farther apart. The electric force is a long-range force, so protons that are far apart still are repelled by the electric force, as shown in Figure 3.

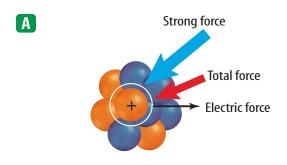


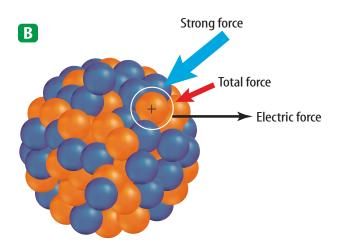
**Figure 3** The total force between two protons depends on how far apart they are. **Infer** whether the total force between two protons could become zero.



When protons are close together, they are attracted to each other. The attraction due to the short-range strong force is much stronger than the repulsion due to the long-range electric force.

When protons are too far apart to be attracted by the strong force, they still are repelled by the electric force between them. Then the total force between them is repulsive.





**Figure 4** Protons and neutrons are held together less tightly in large nuclei. The circle shows the range of the attractive strong force. A Small nuclei have few protons, so the repulsive force on a proton due to the other protons is small. **B** In large nuclei, the attractive strong force is exerted only by the nearest neighbors, but all the protons exert repulsive forces. The total repulsive force is large.

Attraction and Repulsion Some atoms, such as uranium, have many protons and neutrons in their nuclei. These nuclei are held together less tightly than nuclei containing only a few protons and neutrons. To understand this, look at Figure 4A. If a nucleus has only a few protons and neutrons, they are all close enough together to be attracted to each other by the strong force. Because only a few protons are in the nucleus, the total electric force causing protons to repel each other is small. As a result, the overall force between the protons and the neutrons attracts the particles to each other.

Forces in a Large Nucleus However, if nuclei have many protons and neutrons, each proton or neutron is attracted to only a few neighbors by the strong force, as shown in Figure 4B. The other protons and neutrons are too far away. Because only the closest protons and neutrons attract each other in a large nucleus, the strong force holding them together is about the same as in a small nucleus. However, all the protons in a

large nucleus exert a repulsive electric force on each other. Thus, the electric repulsive force on a proton in a large nucleus is larger than it would be in a small nucleus. Because the repulsive force increases in a large nucleus while the attractive force on each proton or neutron remains about the same, protons and neutrons are held together less tightly in a large nucleus.

# **Radioactivity**

Many types of nuclei are held together permanently and are stable. However, there are many other types of nuclei that are unstable. These nuclei break apart, or decay, by emitting particles and energy. This process of nuclear decay is called radioactivity. A nucleus that decays is called a radioactive nucleus.

Nuclei that contain large numbers of protons and neutrons tend to be unstable. In fact, all nuclei that contain more than 83 protons are radioactive. However, many other nuclei that contain fewer than 83 protons also are radioactive. Even some nuclei with only one or a few protons are radioactive.

Almost all elements with more than 92 protons don't exist naturally on Earth. They have been produced only in laboratories and are called synthetic elements. These synthetic elements are unstable and decay soon after they are created.

**Converting Mass into Energy** When an unstable nucleus decays, energy is emitted. If energy is conserved and cannot be created or destroyed, where does this energy come from? Recall that in nuclear reactions, mass can be converted into energy. As an unstable nucleus decays, a small amount of mass is converted into energy. As a result, the mass of the initial nucleus is slightly larger than the mass of the final nucleus plus the mass of any particles that are emitted. A large amount of energy is produced by the conversion of only a small amount of mass.

**Isotopes** The atoms of an element all have the same number of protons in their nuclei. For example, the nuclei of all carbon atoms contain six protons. However, naturally occurring carbon nuclei can have six, seven, or eight neutrons. Nuclei that have the same number of protons but different numbers of neutrons are called isotopes. The element carbon has three isotopes that occur naturally. The atoms of all isotopes of an element have the same number of electrons and have the same chemical properties. **Figure 5** shows two isotopes of helium.

**Nuclear Numbers** A nucleus can be described by the number of protons and neutrons it contains. The number of protons in a nucleus is called the atomic number. Because the mass of all the protons and neutrons in a nucleus is nearly the same as the mass of the atom, the number of protons and neutrons is called the mass number.

### Reading Check What is the atomic number of a nucleus?

A nucleus can be represented by a symbol that includes its atomic number, mass number, and the symbol of the element it belongs to. The symbol for the nucleus of the stable isotope of carbon is shown below as an example.

$$\begin{array}{c} \text{mass number} \rightarrow \ 12 \\ \text{atomic number} \rightarrow \ \ 6 \\ \text{C} \leftarrow \text{element symbol} \end{array}$$

This isotope is called carbon-12. The number of neutrons in the nucleus is the mass number minus the atomic number. So the number of neutrons in the carbon-12 nucleus is 12 - 6 = 6. Carbon-12 has six protons and six neutrons. Now, compare the isotope carbon-12 to this radioactive isotope of carbon:

$$\begin{array}{c} \text{mass number} \rightarrow \ 14 \\ \text{atomic number} \rightarrow \ \ 6 \\ \text{C} \leftarrow \text{element symbol} \end{array}$$

The radioactive isotope is carbon-14. How many neutrons does carbon-14 have?





Helium-3

Helium-4

Figure 5 These two isotopes of helium each have the same number of protons, but different numbers of neutrons. **Identify** the ratio of protons to

neutrons in each of these isotopes of helium.



#### **Modeling the Strong Force**

#### **Procedure**

- **1.** Complete the safety form.
- 2. Gather 15 yellow candies to represent neutrons and 13 red and 2 green candies to represent protons.
- 3. Model a small nucleus by placing two red protons and three neutrons around a green proton so they touch.
- **4.** Model a larger nucleus by arranging the remaining candies around the other green proton so they are touching.

#### **Analysis**

- **1.** Compare the number of protons and neutrons touching a green proton in both models.
- **2.** Suppose the strong force on a green proton is due to protons and neutrons that touch it. Compare the strong force in both models.

**Figure 6** The dark spots on this photographic plate were made by the radiation emitted by radioactive uranium atoms. Uranium salt had been placed next to the plate by Henri Becauerel in 1896.





#### **Topic: Marie Curie**

Visit gpescience.com for Web links to information about the life of Marie Curie.

**Activity** Create a timeline showing important events in the life of Marie Curie.



The Discovery of Radioactivity In 1896, Henri Becquerel left uranium salt in a

desk drawer with a photographic plate. Later, when he developed the plate, shown in Figure 6, he found an outline of the clumps of the uranium salt. He hypothesized that the uranium salt had emitted some unknown invisible rays, or radiation, that had darkened the film.

Two years after Becquerel's discovery, Marie and Pierre Curie discovered two new elements, polonium and radium, that also were radioactive. To obtain a sample of radium large enough to be studied, they developed a process to extract radium from the mineral pitchblende. After more than three years, they were able to obtain about 0.1 g of radium from several tons of pitchblende. Years of additional processing gradually produced more radium that was made available to other researchers all over the world.

#### section

### review

#### **Summary**

#### The Strong Force

- The short-ranged strong force causes neutrons and protons to be attracted to each other.
- The long-ranged electric force causes protons to repel each other.
- The combination of the strong and electric forces causes protons and neutrons in a large nucleus to be held together less tightly than in a small nucleus.

#### **Radioactivity and Isotopes**

- Radioactivity is the process of nuclear decay.
- Isotopes of an element have the same number of protons, but different numbers of neutrons.
- The atomic number is the number of protons in a nucleus. The mass number is the number of protons and neutrons in a nucleus.

#### **Self Check**

- 1. **Describe** the properties of the strong force.
- **2. Compare** the strong force between protons and neutrons in a small nucleus and a large nucleus.
- 3. Explain why large nuclei are unstable.
- 4. Identify the contributions of the three scientists who discovered the first radioactive elements.
- 5. Think Critically What is the ratio of protons to neutrons in lead-214? Explain whether you would expect this isotope to be radioactive or stable.

#### **Applying Math**

- **6. Calculate a Ratio** What is the ratio of neutrons to protons in a nucleus of radon-222?
- 7. Use Percentages A silicon rod contains 30.21 g of silicon-28, 1.53 g of silicon-29, and 1.02 g of silicon-30. Calculate the percentage of each isotope in the rod.

# **Nuclear Decay**

#### **Reading Guide**

#### *What* You'll Learn

- Compare and contrast alpha, beta, and gamma radiation.
- **Define** the half-life of a radioactive material.
- **Describe** the process of radioactive dating.

# Why It's Important

Nuclear decay produces nuclear radiation that can both harm people and be useful.

#### Review Vocabulary

electromagnetic wave: a transverse wave consisting of vibrating electric and magnetic fields

#### **New Vocabulary**

- alpha particle
- transmutation
- beta particle
- gamma ray
- half-life

#### **Nuclear Radiation**

When an unstable nucleus decays, particles and energy called nuclear radiation are emitted from it. The three types of nuclear radiation are alpha, beta (BAY tuh), and gamma radiation. Alpha and beta radiation are particles. Gamma radiation is an electromagnetic wave.

# **Alpha Particles**

When alpha radiation occurs, an alpha particle—made of two protons and two neutrons, as shown in **Table 1**—is emitted from the decaying nucleus. An alpha particle is the same as the nucleus of a helium atom. It has a charge of +2 and an atomic mass of 4. Its symbol is the same as the symbol of a helium nucleus, <sup>4</sup>He.

Reading Check What does an alpha particle consist of?

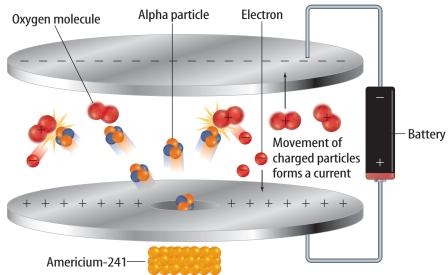
Compared to beta and gamma radiation, alpha particles are much more massive. They also have the most electric charge. As a result, alpha particles lose energy more quickly when they interact with matter than the other types of nuclear radiation do. When alpha particles pass through matter, they exert an electric force on the electrons in atoms in their path. This force pulls electrons away from atoms and leaves behind charged ions. Alpha particles lose energy quickly during this process. As a result, alpha particles are the least penetrating form of nuclear radiation. Alpha particles can be stopped by a sheet of paper.

#### **Table 1 Alpha Particles**

+		
Symbol	<sup>4</sup> <sub>2</sub> He	
Mass	4	
Charge	+2	

**Figure 7** When alpha particles collide with molecules in the air, positively charged ions and electrons result. The ions and electrons move toward charged plates, creating a current in the smoke detector.





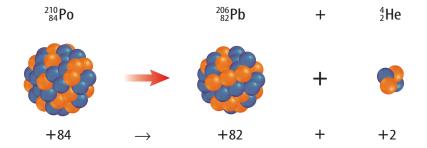
Damage from Alpha Particles Alpha particles can be dangerous if they are released by radioactive atoms inside the human body. Biological molecules inside your body are large and easily damaged. A single alpha particle can damage many fragile biological molecules. Damage from alpha particles can cause cells not to function properly, leading to illness and disease.

**Smoke Detectors** Some smoke detectors give off alpha particles that ionize the surrounding air. Normally, an electric current flows through this ionized air to form a circuit, as in **Figure 7.** But if smoke particles enter the ionized air, they will absorb the ions and electrons. The circuit is broken and the alarm goes off.

**Transmutation** When an atom emits an alpha particle, it has two fewer protons, so it is a different element. **Transmutation** is the process of changing one element to another through nuclear decay. In alpha decay, two protons and two neutrons are lost from the nucleus. The new element has an atomic number two less than that of the original element. The mass number of the new element is four less than the original element. Figure 8 shows a nuclear transmutation caused by alpha decay. The charge of the original nucleus equals the sum of the charges of the nucleus and the alpha particle that are formed.

Figure 8 In this transmutation, polonium emits an alpha particle and changes into lead.

**Determine** whether the charges and mass numbers of the products equal the charge and mass number of the polonium nucleus.



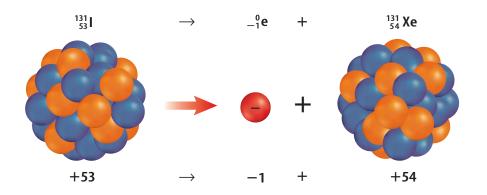


Figure 9 Nuclei that emit beta particles undergo transmutation. In beta decay shown here, iodine changes to xenon.

**Compare** *the total atomic number* and mass number of the products with the atomic number and mass number of the iodine nucleus.

#### **Beta Particles**

A second type of radioactive decay is called beta decay, which is summarized in **Table 2.** Sometimes in an unstable nucleus a neutron decays into a proton and emits an electron. The electron is emitted from the nucleus and is called a **beta particle**. Beta decay is caused by another basic force called the weak force.

Because the atom now has one more proton, it becomes the element with an atomic number one greater than that of the original element. Atoms that lose beta particles undergo transmutation. However, because the total number of protons and neutrons does not change during beta decay, the mass number of the new element is the same as that of the original element. **Figure 9** shows a transmutation caused by beta decay.

**Damage from Beta Particles** Beta particles are much faster and more penetrating than alpha particles. They can pass through paper but are stopped by a sheet of aluminum foil. Just like alpha particles, beta particles can damage cells when they are emitted by radioactive nuclei inside the human body.

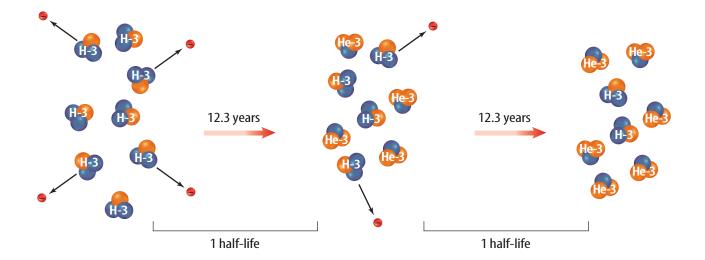
## **Gamma Rays**

The most penetrating form of nuclear radiation is gamma radiation. Gamma rays are electromagnetic waves with the highest frequencies and the shortest wavelengths in the electromagnetic spectrum. They have no mass and no charge and travel at the speed of light. They usually are emitted from a nucleus when alpha decay or beta decay occurs. The properties of gamma rays are summarized in **Table 3.** 

Thick blocks of dense materials, such as lead and concrete, are required to stop gamma rays. However, gamma rays cause less damage to biological molecules as they pass through living tissue. Suppose an alpha particle and a gamma ray travel the same distance through matter. The gamma ray produces fewer ions because it has no electric charge.

Table 2 Beta Particles	
<b>○</b> → <b>○</b> + <b>+</b>	
Symbol	_0 <b>e</b>
Mass	0.0005
Charge	-1

Table 3 Gamma Rays	
<b>~~~</b>	
Symbol	γ
Mass	0
Charge	0



**Figure 10** The half-life of <sup>3</sup>H is 12.3 years. During each half-life, half of the atoms in the sample decay into helium.

**Infer** how many hydrogen atoms will be left in the sample after the next half-life.

Table 4 Sample Half-Lives	
Isotope	Half-Life
3H	12.3 years
<sup>212</sup> Pb	10.6 hr
<sup>14</sup> C	5,730 years
<sup>211</sup> Po	0.5 s
<sup>235</sup> U	$7.04  imes 10^8$ years
131 <sub>53</sub> 1	8.04 days

#### **Radioactive Half-Life**

If an element is radioactive, how can you tell when its atoms are going to decay? Some radioisotopes decay to stable atoms in less than a second. However, the nuclei of certain radioactive isotopes require millions of years to decay. A measure of the time required by the nuclei of an isotope to decay is called the half-life. The **half-life** of a radioactive isotope is the amount of time it takes for half the nuclei in a sample of the isotope to decay. The nucleus left after the isotope decays is called the daughter nucleus. **Figure 10** shows how the number of decaying nuclei decreases after each half-life.

Half-lives vary widely among the radioactive isotopes. For example, polonium-214 has a half-life of less than a thousandth of a second, but uranium-238 has a half-life of 4.5 billion years. The half-lives of some other radioactive elements are listed in **Table 4.** 



# **Radioactive Dating**

Some geologists, biologists, and archaeologists, among others, are interested in the ages of rocks and fossils found on Earth. The ages of these materials can be determined using radioactive isotopes and their half-lives. First, the amounts of the radioactive isotope and its daughter nucleus in a sample of material are measured. Then, the number of half-lives that need to pass to give the measured amounts of the isotope and its daughter nucleus is calculated. The number of half-lives is the amount of time that has passed since the isotope began to decay. Also, it is usually the amount of time that has passed since the object was formed, or the age of the object. Different isotopes are useful in dating different types of materials.

**Carbon Dating** The radioactive isotope carbon-14 often is used to estimate the ages of plant and animal remains. Carbon-14 has a half-life of 5,730 years and is found in molecules such as carbon dioxide. Plants use carbon dioxide when they make food, so all plants contain carbon-14. When animals eat plants, carbon-14 is added to their bodies.

The decaying carbon-14 in a plant or animal is replaced when an animal eats or when a plant makes food. As a result, the ratio of the number of carbon-14 atoms to the number of carbon-12 atoms in the organism remains nearly constant. But when an organism dies, its carbon-14 atoms decay without being replaced. The ratio of carbon-14 to carbon 12 then decreases with time. By measuring this ratio, the age of an organism's remains can be estimated. However, only material from plants and animals that lived within the past 50,000 years contains enough carbon-14 to be measured.

**Uranium Dating** Radioactive dating also can be used to estimate the ages of rocks. Some rocks contain uranium, which has two radioactive isotopes with long half-lives. Each of these uranium isotopes decays into a different isotope of lead. The number of these uranium isotopes and their daughter nuclei are measured. From the ratios of these amounts, the number of half-lives since the rock was formed can be calculated.

#### section гечіеш

#### Summary

#### **Nuclear Radiation**

- When an unstable nucleus decays it emits nuclear radiation that can be alpha particles, beta particles, or gamma rays.
- An alpha particle consists of two protons and two neutrons.
- A beta particle is an electron and is emitted when a neutron decays into a proton.
- Gamma rays are electromagnetic waves of very high frequency that usually are emitted when alpha decay or beta decay occurs.

#### **Half-Life and Radioactive Dating**

- The half-life of a radioactive isotope is the amount of time for half the nuclei in a sample of the isotope to decay.
- The amounts of radioactive isotopes and their daughter nuclei are needed to date materials.

#### Self Check

- 1. Infer how the mass number and the atomic number of a nucleus change when it emits a beta particle.
- 2. **Determine** the daughter nucleus formed when a radon-222 nucleus emits an alpha particle.
- 3. **Describe** how each of the three types of radiation can be stopped.
- **4. Think Critically** Sample 1 contains nuclei with a halflife of 10.6 hr and sample 2 contains an equal number of nuclei with a half-life of 0.5 s. After 3 half-lives pass for each sample, which sample contains more of the original nuclei?

#### **Applying Math**

- **5. Use Percentages** What is the percentage of radioactive nuclei left after 3 half-lives pass?
- **6. Use Fractions** If the half-life of iodine-131 is 8 days, how much of a 5-g sample is left after 32 days?

# **Detecting Radioactivity**

#### **Reading Guide**

#### What You'll Learn

- Describe how radioactivity can be detected in cloud and bubble chambers.
- **Explain** how an electroscope can be used to detect radiation.
- **Explain** how a Geiger counter can measure nuclear radiation.

# Why It's Important

Devices that detect and measure radioactivity are used to monitor exposure to humans.

#### Review Vocabulary

ion: an atom that has gained or lost electrons

#### **New Vocabulary**

- cloud chamber
- bubble chamber
- Geiger counter

#### **Radiation Detectors**

Because you can't see or feel alpha particles, beta particles, or gamma rays, you must use instruments to detect their presence. Some tools that are used to detect radioactivity rely on the fact that radiation forms ions in the matter it passes through. The tools detect these newly formed ions in several ways.

Cloud Chambers A cloud chamber, shown in Figure 11, can be used to detect alpha or beta particle radiation. A cloud chamber is filled with water or ethanol vapor. When a radioactive sample is placed in the cloud chamber, it gives off charged alpha or beta particles that travel through the water or ethanol vapor. As each charged particle travels through the chamber, it knocks electrons off the atoms in the air, creating ions. It leaves a trail of ions in the chamber. The water or ethanol vapor condenses around these ions, creating a visible path of droplets along the track of the particle. Beta particles leave long, thin trails, and alpha particles leave shorter, thicker trails.

Reading Check

Why are trails produced by alpha and beta particles seen in cloud chambers?

**Figure 11** If a sample of radioactive material is placed in a cloud chamber, a trail of condensed vapor will form along the paths of the emitted particles.



Bubble Chambers Another way to detect and monitor the paths of nuclear particles is by using a bubble chamber. A bubble chamber holds a superheated liquid, which doesn't boil because the pressure in the chamber is high. When a moving particle leaves ions behind, the liquid boils along the trail. The path shows up as tracks of bubbles, like the ones in Figure 12.

**Electroscopes** Do you remember how an electroscope can be used to detect electric charges? When an electroscope is given a negative charge, its leaves repel each other and spread apart, as in **Figure 13A.** They will

remain apart until their extra electrons have somewhere to go and discharge the electroscope. The excess charge can be neutralized if it combines with positive charges. Nuclear radiation moving through the air can remove electrons from some molecules in air, as shown in **Figure 13B**, and cause other molecules in air to gain electrons. When this occurs near the leaves of the electroscope, some positively charged molecules in the air can come in contact with the electroscope and attract the electrons from the leaves, as **Figure 13C** shows. As these negatively charged leaves lose their charges, they move together. **Figure 13D** shows this last step in the process. The same process also will occur if the electroscope leaves are positively charged. Then the electrons move from negative ions in the air to the electroscope leaves.



**Figure 12** Particles of nuclear radiation can be detected as they leave trails of bubbles in a bubble chamber.

**Figure 13** Nuclear radiation can cause an electroscope to lose its charge.



A The electroscope leaves are charged with negative charge.



**B** Nuclear radiation, such as alpha particles, can create positive ions.



Negative charges move from the leaves to positively charged ions.



D The electroscope leaves lose their negative charge and come together.

# **Measuring Radiation**

It is important to monitor the amount of radiation a person is being exposed to because large doses of radiation can be harmful to living tissue. A **Geiger counter** is a device that measures the amount of radiation by producing an electric current when it detects a charged particle.

#### **Applying Math**

#### **Use Logarithms**

**THE AGE OF ROCKS** The radioactive nucleus uranium-238 produces the daughter nucleus lead-206 with a half-life of 4.5 billion years. The age of a mineral sample can be calculated from the equation:

$$age = (1.44H)\ln\left[1 + \frac{N_{\rm L}}{N_{\rm H}}\right]$$

In this equation, H is the half-life of uranium 238,  $N_{\rm L}$  is the number of lead-206 atoms in the sample, and  $N_{\rm U}$  is the number of uranium-238 atoms in the sample. Find the age of a sample in which the ratio  $N_{\rm L}/N_{\rm U}$  is measured to be 0.55.

#### IDENTIFY known values and unknown values

#### Identify the known values:

the ratio of the number of uranium-238 atoms  $\frac{N_L}{N_U} = 0.55$  to the number of lead-206 atoms is 0.55

a half-life of 4.5 billion years H = 4.5 billion years

Identify the unknown value:

what is the age of the sample?  $\longrightarrow$  age = ? years

#### SOLVE the problem

Substitute the known values into the equation for the age:

age = 
$$(1.44H)\ln\left[1 + \frac{N_L}{N_U}\right] = (1.44 \times 4.5 \text{ billion yrs}) \ln\left[1 + 0.55\right]$$
  
=  $(6.48 \text{ billion yrs}) \ln(1.55)$ 

To calculate ln(1.55), enter 1.55 on your calculator and press the "ln" button. The result is 0.438. Substitute this value in the above equation:

$$age = (6.48 \text{ billion yrs})(0.438) = 2.84 \text{ billion yrs}$$

#### **CHECK** the answer

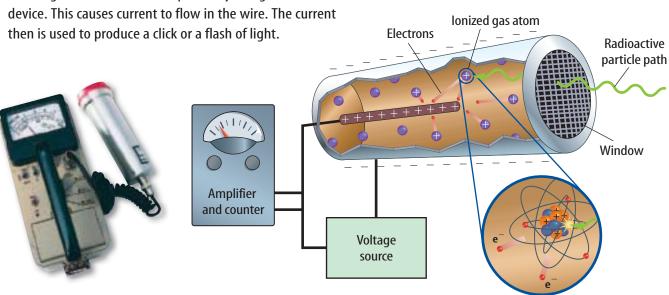
Does your answer seem reasonable? The ratio  $N_{\rm L}/N_{\rm U}=0.55$ , means that less than one half-life has elapsed. The calculated age is less than one half-life.

#### **Practice Problems**

Find the age of a sample in which the ratio  $N_{\rm L}/N_{\rm U}$  has been measured to be 1.21.

For more practice problems go to page 879, and visit Math Practice at gpescience.com.

**Figure 14** Electrons that are stripped off gas molecules in a Geiger counter move to a positively charged wire in the device. This causes current to flow in the wire. The current



**Geiger Counters** A Geiger counter, shown in **Figure 14**, has a tube with a positively charged wire running through the center of a negatively charged copper cylinder. This tube is filled with gas at a low pressure. When radiation enters the tube at one end, it knocks electrons from the atoms of the gas. These electrons then knock more electrons off other atoms in the gas, and an "electron avalanche" is produced. The free electrons are attracted to the positive wire in the tube. When a large number of electrons reaches the wire, a short, intense current is produced in the wire. This current is amplified to produce a clicking sound or flashing light. The intensity of radiation present is determined by the number of clicks or flashes of light each second.



How does a Geiger counter indicate that radiation is present?

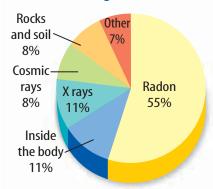
# **Background Radiation**

It might surprise you to know that you are bathed in radiation that comes from your environment. This radiation, called background radiation, is not produced by humans. Instead it is low-level radiation emitted mainly by naturally occurring radioactive isotopes found in Earth's rocks, soils, and atmosphere. Building materials such as bricks, wood, and stones contain traces of these radioactive materials. Traces of naturally occurring radioactive isotopes are found in the food, water, and air consumed by all animals and plants. As a result, animals and plants also contain small amounts of these isotopes.



Artificial Rainmaking It may be possible to ease the health and economic hardships caused by severe droughts by artificially making rain. The formation of raindrops in a cloud is similar to the formation of droplets in a cloud chamber. Rain forms when cold droplets freeze around microscopic particles of dust, and then melt as they fall through warmer air. Research artificial rainmaking and report your findings to your class.

#### **Sources of Background Radiation**



**Figure 15** This circle graph shows the average amount of background radiation from different sources received by a person living in the United States.

**Sources of Background Radiation** Background radiation comes from several sources, as shown in **Figure 15.** The largest source comes from the decay of radon gas. Radon, which emits an alpha particle when it decays, is produced in Earth's crust by the decay of uranium-238. Radon gas can seep into houses and basements from the surrounding soil and rocks.

Some background radiation comes from high-speed nuclei, called cosmic rays, that strike Earth's atmosphere. They produce showers of particles, including alpha, beta, and gamma radiation. Most of this radiation is absorbed by the atmosphere. Higher up there is less atmosphere to absorb this radiation, so the background radiation from cosmic rays increases with altitude.

**Radiation in Your Body** Some of the elements that are essential for life have naturally occurring radioactive isotopes. For example, about one out of every trillion carbon atoms is carbon-14, which emits a beta particle when it decays. With each breath, you inhale about 3 million carbon-14 atoms.

The amount of background radiation a person receives can vary greatly. The amount depends on the type of rocks underground, the type of materials used to construct the person's home, and the elevation at which the person lives, among other things. However, because it comes from naturally occurring processes, background radiation never can be eliminated.

# section

#### review

#### **Summary**

#### **Radiation Detectors**

- Alpha and beta particles can be detected by the trail of ions they form when they pass through a cloud chamber or a bubble chamber.
- The presence of alpha or beta particles can cause an electroscope to become discharged.
- A Geiger counter is used to measure radiation levels. It produces a clicking sound or a flash of light when alpha or beta particles enter the Geiger counter tube.

#### **Background Radiation**

- Background radiation is low-level radiations emitted mainly by radioactive isotopes in Earth's rocks, soils, and atmosphere.
- The largest source of background radiation is from the alpha decay of radon gas.

#### Self Check

- **1. Describe** why a charged electroscope will discharge when placed near a radioactive material.
- **2. Compare and contrast** cloud and bubble chambers.
- 3. **Describe** the process that occurs in a Geiger counter when radiation is detected.
- **4. Explain** why background radiation never can be completely eliminated.
- **5. Think Critically** If the radioactive isotope radon-222 has a half-life of only four days, how can radon gas be continually present inside houses?

#### **Applying Math**

**6. Use Percentages** The amount of radiation can be measured in units called millirems. If 25 millirems from cosmic rays is 8.0 percent of the average background radiation, what is the amount of the average background radiation in millirems?



# **Nuclear Reactions**

#### **Reading Guide**

#### What You'll Learn

- can begin a chain reaction.
- **Discuss** how nuclear fusion occurs in the Sun.
- Describe how radioactive tracers can be used to diagnose medical problems.
- **Discuss** how nuclear reactions can help treat cancer.

# Why It's Important

**Explain** nuclear fission and how it Almost all of the different atoms that you are made of were formed by the nuclear reactions inside ancient, distant stars.

#### Review Vocabulary

kinetic energy: energy of motion; increases as the mass or speed of an object increases

#### **New Vocabulary**

- nuclear fission
- chain reaction
- critical mass
- nuclear fusion
- tracer

#### **Nuclear Fission**

In the 1930s, physicist Enrico Fermi thought that by bombarding nuclei with neutrons, nuclei would absorb neutrons and heavier nuclei would be produced. However, in 1938, Otto Hahn and Fritz Strassmann found that when a neutron strikes a uranium-235 nucleus, the nucleus splits apart into smaller nuclei.

In 1939 Lise Meitner was the first to offer a theory to explain these results. She proposed that the uranium-235 nucleus is so distorted when the neutron strikes it that it divides into two smaller nuclei, as shown in **Figure 16.** The process of splitting a nucleus into several smaller nuclei is **nuclear fission**. The word fission means "to divide."

#### Reading Check

What initiates nuclear fission of a uranium-235

Only large nuclei, such as the nuclei of uranium and plutonium, undergo nuclear fission. A fission reaction usually produces several individual neutrons in addition to the

smaller nuclei. The total mass of the products is slightly less than the mass of the original nucleus and the neutron. This small amount of missing mass is converted to a tremendous amount of energy during the fission reaction.

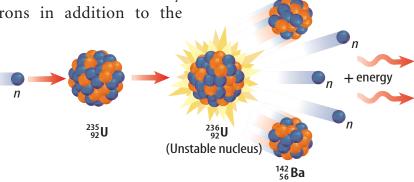
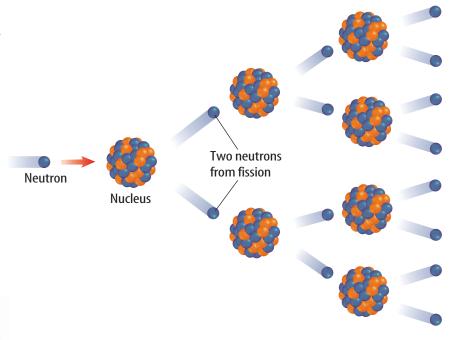


Figure 16 When a neutron hits a uranium-235 nucleus, the uranium nucleus splits into two smaller nuclei and two or three free neutrons. Energy also is released.

**Figure 17** A chain reaction occurs when neutrons emitted from a split nucleus cause other nuclei to split and emit additional neutrons.





#### **Modeling a Nuclear** Reaction

#### 

- **1.** Complete the safety form.
- 2. Place 32 marbles, each with an attached lump of clay, into a large beaker. These marbles with clay represent unstable atoms.
- 3. During a 1-min period, remove half of the marbles and pull off the clay. Place the removed marbles into another beaker and place the lumps of clay into a pile. Marbles without clay represent stable atoms. The clay represents waste from the reaction smaller atoms that still might decay and give off
- **4.** Repeat this procedure four more times.

#### **Analysis**

- 1. What is the half-life of this reaction?
- 2. Explain whether the waste products could undergo nuclear fission.

Mass and Energy Albert Einstein proposed that mass and energy were related in his special theory of relativity. According to this theory, mass can be converted to energy and energy can be converted to mass. The relation between mass and energy is given by this equation:

#### **Mass-Energy Equation**

Energy (joules) = mass (kg) × [speed of light (m/s)]<sup>2</sup>

$$E = mc^{2}$$

A small amount of mass can be converted into an enormous amount of energy. For example, if one gram of mass is converted to energy, about 100 trillion joules of energy are released.

**Chain Reactions** When a nuclear fission reaction occurs, the neutrons emitted can strike other nuclei in the sample and cause them to split. These reactions then release more neutrons, causing additional nuclei to split, as shown in **Figure 17.** The series of repeated fission reactions caused by the release of neutrons in each reaction is a chain reaction.

If the chain reaction is uncontrolled, an enormous amount of energy is released in an instant. However, a chain reaction can be controlled by adding materials that absorb neutrons. If enough neutrons are absorbed, the reaction will continue at a constant rate.

For a chain reaction to occur, a critical mass of material that can undergo fission must be present. The critical mass is the amount of material required so that each fission reaction produces approximately one more fission reaction. If less than the critical mass of material is present, a chain reaction will not occur.

#### **Nuclear Fusion**

Even though nuclear fission reactions release tremendous amounts of energy, even more energy can be released by nuclear fusion reactions. In a nuclear fusion reaction, two nuclei with small masses combine to form a nucleus of larger mass. Nuclear fission reactions release millions of times more energy than can be released by chemical reactions.

The reason nuclear reactions release so much more energy than chemical reactions is that the strong force is much stronger than the electric force. This means that the nuclear potential energy stored in atomic nuclei is much greater than the chemical potential energy stored in chemical bonds between atoms.

**Temperature and Fusion** For nuclear fusion to occur, positively charged nuclei must get close to each other. However, nuclei repel each other because they have the same positive electric charge. If nuclei are moving fast, they can have enough kinetic energy to overcome the repulsive electrical force between them and get close to each other.

Remember that the kinetic energy of atoms or molecules increases as their temperature increases. Only at temperatures of millions of degrees Celsius are nuclei moving so fast that they can get close enough for fusion to occur. These extremely high temperatures are found in the center of stars, such as the Sun.

**Nuclear Fusion and the Sun** The Sun is composed mainly of hydrogen. Most of the energy given off by the Sun is produced by a process involving the fusion of hydrogen nuclei. This process occurs in several stages, and one of the stages is shown in **Figure 18.** The net result of this process is that four hydrogen

nuclei are converted into one helium nucleus. As these nuclear reactions occur, a small amount of mass is changed into an enormous amount of energy. Earth receives a small amount of this energy as thermal energy and light.

As the Sun ages, the hydrogen nuclei are used up as they are converted into helium. So far, only about one percent of the Sun's mass has been converted into energy. It is estimated that the Sun has enough hydrogen to keep this reaction going for another 5 billion years.

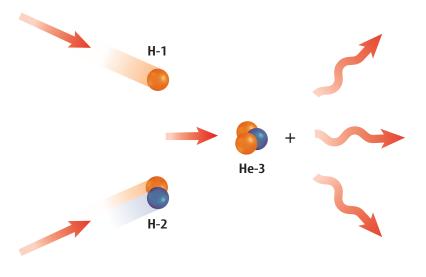


#### **Topic: Fusion Reactors**

Visit **gpescience.com** for Web links to information about the use of nuclear fusion as a future energy source.

**Activity** Write a paragraph describing the different types of fusion reactors that have been developed.

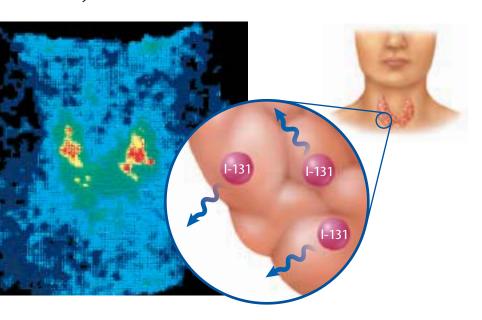
**Figure 18** The fusion of hydrogen to form helium takes place in several stages in the Sun. One of these stages is shown here. An isotope of helium is produced when a proton and the hydrogen isotope H-2 undergo fusion.





**Radioactive Decay Equations** A uranium-235 atom can fission, or break apart, to form barium and krypton. Use a periodic table to find the atomic numbers of barium and krypton. What do they add up to? A uranium-235 atom can fission in several other ways such as producing neodymium and another element. What is the other element?

Figure 19 Radioactive iodine-131 accumulates in the thyroid gland and emits gamma rays, which can be detected to form an image of a patient's thyroid. **List** some advantages of being able to use iodine-131 to form an image of a thyroid.



## **Using Nuclear Reactions in Medicine**

If you were going to meet a friend in a crowded area, it would be easier to find her if she told you that she would be wearing a red hat. In a similar way, scientists can find one molecule in a large group of molecules if they know that it is "wearing" something unique. Although a molecule can't wear a red hat, if it has a radioactive atom in it, it can be found easily in a large group of molecules, or even in a living organism. Radioactive isotopes can be located by detecting the radiation they emit.

When a radioisotope is used to find or keep track of molecules in an organism, it is called a tracer. Scientists can use tracers to follow where a particular molecule goes in your body or to study how a particular organ functions. Tracers also are used in agriculture to monitor the uptake of nutrients and fertilizers. Examples of tracers include carbon-11, iodine-131, and sodium-24. These three radioisotopes are useful tracers because they are important in certain body processes. As a result, they accumulate inside the organism being studied.

Reading Check How are tracers located inside the human body?

**lodine Tracers in the Thyroid** The thyroid gland is located in your neck and pro-

duces chemical compounds called hormones. These hormones help regulate several body processes, including growth. Because the element iodine accumulates in the thyroid, the radioisotope iodine-131 can be used to diagnose thyroid problems. As iodine-131 atoms are absorbed by the thyroid, their nuclei decay, emitting beta particles and gamma rays. The beta particles are absorbed by

> the surrounding tissues, but the gamma rays penetrate the skin. The emitted gamma rays can be detected and used to determine whether the thyroid is healthy, as shown in **Figure 19.** If the detected radiation is not intense, then the thyroid has not properly absorbed the iodine-131 and is not functioning properly. This could be due to the presence of a tumor. **Figure 20** shows how radioactive tracers are used to study the brain.

# NATIONAL GEOGRAPHIC VISUALIZING PET SCANS

#### Figure 20

he diagram below shows an imaging technique known as Positron Emission Tomography, or PET. Positrons are emitted from the nuclei of certain radioactive isotopes when a proton changes to a neutron. PET can form images that show the level of activity in different areas of the brain. These images can reveal tumors and regions of abnormal brain activity.

B The radioactive isotope fluorine-18 emits positrons when it decays. Fluorine-18 atoms are chemically attached to molecules that are absorbed by brain tissue. These compounds are injected into the patient and carried by blood to the brain.

Inside the patient's brain, the decay of the radioactive fluorine-18 nuclei emits positrons that collide with electrons. The gamma rays that are released are sensed by the detectors.

D A computer uses the information collected by the detectors to generate an image of the activity level in the brain. This image shows normal activity in the right side of the brain (red, yellow, green) but below-normal activity in the left (purple).

they can hit electrons from other atoms and become transformed into gamma rays. A Gamma ray

A When positrons

are emitted from the

nucleus of an atom,



Figure 21 Cancer cells, such as the ones shown here, can be killed with carefully measured doses of radiation.

# Treating Cancer with Radioactivity

When a person has cancer, a group of cells in that person's body grows out of control and can form a tumor. Radiation can be used to stop some types of cancerous cells from growing. Remember that the radiation that is given off during nuclear decay is strong enough to ionize nearby atoms. If a source of radiation is placed near cancer cells, such as those shown in Figure 21, atoms in the cells can be ionized. If the ionized atoms are in a

critical molecule, such as the DNA or RNA of a cancer cell, then the molecule might no longer function properly. The cell then could die or stop growing.

When possible, a radioactive isotope such as gold-198 or iridium-192 is implanted within or near the tumor. Other times, tumors are treated from outside the body. Typically, an intense beam of gamma rays from the decay of cobalt-60 is focused on the tumor for a short period of time. The gamma rays pass through the body and into the tumor. How can physicians be sure that only the cancer cells will absorb radiation? Because cancer cells grow quickly, they are more susceptible to absorbing radiation and being damaged than healthy cells are. However, other cells in the body that grow quickly also are damaged, which is why cancer patients who have radiation therapy sometimes experience severe side effects.

# section

# **Summary**

#### **Nuclear Fission**

- Nuclear fission occurs when a neutron strikes a nucleus, causing it to split into smaller nuclei.
- A chain reaction requires a critical mass of fissionable material.

#### **Nuclear Fusion**

- Nuclear fusion occurs when two nuclei combine to form another nucleus.
- Nuclear fusion occurs at temperatures of millions of degrees, which occur inside the Sun.

#### **Medical Uses of Radiation**

- Radioactive isotopes are used as tracers to locate various atoms or molecules in organisms.
- Radiation emitted by radioactive isotopes is used to kill cancer cells.

## **Self Check**

- 1. Infer whether mass is conserved in a nuclear reaction.
- 2. Explain why fusion reactions can occur inside stars.
- 3. Explain how a chain reaction can be controlled.

review

- **4. Describe** two properties of a tracer isotope used for monitoring the functioning of an organ in the body.
- **5. Think Critically** Explain why high temperatures are needed for fusion reactions to occur, but not for fission reactions to occur.

# Applying <u>Math</u>

**6. Calculate Number of Nuclei** In a chain reaction, two neutrons are emitted by each nucleus that is split. If one nucleus is split in the first step of the reaction, how many nuclei will have been split after the fifth step?



# Chain Reactions

In an uncontrolled nuclear chain reaction, the number of reactions increases as additional neutrons split more nuclei. In a controlled nuclear reaction, neutrons are absorbed, so the reaction continues at a constant rate. How could you model a controlled and an uncontrolled nuclear reaction in the classroom?



How can you model chain reactions?

#### Goals

- Model a controlled and uncontrolled chain reaction.
- **Compare** the two types of chain reactions.

#### **Materials**

dominoes

stopwatch

# **Safety Precautions**



# Procedure

- 1. Complete the safety form.
- Set up a single line of dominoes standing on end so that when the first domino is pushed over, it will knock over the second and each domino will knock over the one following it.
- **3.** Using the stopwatch, time how long it takes from the moment the first domino is pushed over until the last domino falls over. Record the time.
- **4.** Line up the same number of dominoes in the shape of a Y, as shown above. Be sure that both dominoes at the split in the Y will get knocked down by the falling dominoes.
- 5. Repeat step 3.



# Conclude and Apply

- Compare the amount of time it took for all of the dominoes to fall in each of your two arrangements.
- **2. Determine** the average number of dominoes that fell per second in both domino arrangements.
- **3. Identify** which of your domino arrangements represented a controlled chain reaction and which represented an uncontrolled chain reaction.
- 4. Describe how the concept of critical mass was represented in your model of a controlled chain reaction.
- 5. Assuming that they had equal amounts of material, which would finish faster—a controlled or an uncontrolled nuclear chain reaction? Explain.

# Communicating Your Data

**Explain** to friends or members of your family how a controlled nuclear chain reaction can be used in nuclear power plants to generate electricity.



# **Model and Invent**

# Modeling Transmutations

#### Goal

■ **Model** decay of a uranium atom.

#### **Possible Materials**

brown rice
white rice
colored candies
dried beans
dried seeds
glue
poster board

## **Safety Precautions**



**WARNING:** *Never eat foods used in the lab.* 

#### **Data Source**

Refer to your textbook for general information about transmutation.

# 🧶 Real-World Problem

Imagine what would happen if the oxygen atoms around you began changing into nitrogen atoms. Without oxygen, most living organisms, including people, could not live. Fortunately, more than 99.9 percent of all oxygen atoms are stable and do not decay. Usually, when an unstable nucleus decays, an alpha or beta particle is thrown out of its nucleus, and the atom becomes a new element. This process of one element changing into another element is called transmutation. How could you create a model of a uranium-238 atom and the decay process it undergoes during transmutation? What types of materials could you use to represent the protons and neutrons in a U-238 nucleus? How could you use these materials to model transmutation?

# Make a Model

- 1. Complete the safety form.
- **2. Choose** two materials of different colors or shapes for the protons and neutrons of your nucleus model. Choose a material for the negatively charged beta particle.





# Using Scientific Methods

- **3. Decide** how to model the transmutation process. Will you create a new nucleus model for each new element? How will you model an alpha or beta particle leaving the nucleus?
- 4. Create a transmutation chart to show the results of each transmutation step of a uranium-238 atom with the identity, atomic number, and mass number of each new element formed and the type of radiation particle emitted at each step. A uranium-238 atom will undergo the following decay steps before transmuting into a lead-206 atom: alpha decay, beta decay, beta decay, alpha decay, alpha decay, beta decay, beta decay, beta decay, beta decay, beta decay, alpha decay.



- **5. Describe** your model plan and transmutation chart to your teacher and ask how they can be improved.
- Present your plan and chart to your class. Ask classmates to suggest improvements in both.
- **7.** Construct your model of a uranium-238 nucleus showing the correct number of protons and neutrons.

# Test Your Model-

- 1. Using your nucleus model, demonstrate the transmutation of a uranium-238 nucleus into a lead-206 nucleus by following the decay sequence outlined in the previous section.
- **2.** Show the emission of an alpha particle or beta particle between each transmutation step.

# Analyze Your Data

- 1. Compare how alpha and beta decay change an atom's atomic number.
- 2. Compare how alpha and beta decay change the mass number of an atom.

# 🧶 Conclude and Apply-

- **1. Calculate** the ratio of neutrons to protons in lead-206 and uranium-238. In which nucleus is the ratio closer to 1.5?
- **2. Identify** Alchemists living during the Middle Ages spent much time trying to turn lead into gold. Identify the decay processes needed to accomplish this task.



Show your model to the class and explain how your model represents the transmutation of U-238 into Pb-206.

# TIME

# SCIENCE AND HISTORY

SCIENCE
CAN CHANGE
THE COURSE
OF HISTORY!

# The Nuclear Alchemists

The colored tracks are alpha particles emitted from a speck of radium salt placed on a special photographic plate.

or centuries, ancient alchemists tried in vain to convert common metals into gold. However, in the early 20th century, some scientists realized there was a way to convert atoms of some elements into other elements—nuclear fission.

#### **A Startling Discovery**

As the twentieth century dawned, most scientists thought atoms could not be broken apart. In 1902, New Zealand physicist Ernest Rutherford and his colleague Frederick Soddy showed that heavy elements uranium and thorium decayed into slightly lighter elements, with the production of helium gas. "Don't call it transmutation. They'll have our heads off as alchemists!" Rutherford warned Soddy. In 1908, Rutherford showed that the alpha particles emitted in radioactive decay were the same as helium nuclei.

#### **Something's Missing**

In 1938 in Germany, Otto Hahn and Fritz Strassmann found the uranium-235 nucleus

would split if struck by a neutron. The process was called nuclear fission.

Enrico Fermi lead the development of the first nuclear reactor.

A year later, Austrian physicist Lise Meitner pointed out that the total mass of the particles produced when the uranium nucleus split was less than that of the original uranium nucleus. According to the special theory of relativity, this small amount of missing mass results in the release of a tremendous amount of energy when fission occurs. But is there any way this energy can be controlled?



Lise Meitner was the first to explain how nuclear fission occurs.

#### **Controlling a Chain Reaction**

Only a few years later, Italian physicist Enrico Fermi, working with colleagues in the United States, found the answer. Fermi realized that the neutrons released when fission occurs could lead to a chain reaction. However, materials that absorb neutrons could be used to control the chain reaction. In late 1942, Fermi and his colleagues built the first nuclear reactor by using cadmium rods to absorb neutrons and control the chain reaction. The tremendous energy released by nuclear fission could be controlled.

**Research** Find out more about the contributions these scientists made to understanding radioactivity and the nucleus. What other discoveries did Rutherford and Fermi make?

For more information, visit

# Reviewing Main Ideas

# **Section 1** Radioactivity

**1.** The protons and neutrons in an atomic nucleus, like the one to the right, are held together by the strong force.



**Nucleus** 

- **2.** The ratio of protons to neutrons indicates whether a nucleus will be stable or unstable. Large nuclei tend to be unstable.
- **3.** Radioactivity is the emission of energy or particles from an unstable nucleus.
- **4.** Radioactivity was discovered accidentally by Henri Becquerel about 100 years ago.

# **Section 2 Nuclear Decay**

- 1. Unstable nuclei can decay by emitting alpha particles, beta particles, and gamma rays.
- **2.** Alpha particles consist of two protons and two neutrons. A beta particle is an electron.
- **3.** Gamma rays are the highest frequency electromagnetic waves.
- **4.** Half-life is the amount of time in which half of the nuclei of a radioactive isotope will decay.
- **5.** Because all living things contain carbon, the radioactive isotope carbon-14 can be used to date the remains



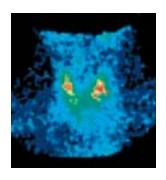
- of organisms that lived during the past 50,000 years, such as this skeleton.
- **6.** Radioactive isotopes of uranium are used to date rocks.

#### Section 3 **Detecting Radioactivity**

- **1.** Radioactivity can be detected with a cloud chamber, a bubble chamber, an electroscope, or a Geiger counter.
- **2.** A Geiger counter measures the amount of radiation by producing electric current when it is struck by a charged particle.
- **3.** Background radiation is low-level radiation emitted by naturally occurring isotopes found in Earth's rocks and soils, the atmosphere, and inside your body.

# **Section 4 Nuclear Reactions**

- **1.** When nuclear fission occurs, a nucleus splits into smaller nuclei. Neutrons and a large amount of energy are emitted.
- 2. Neutrons emitted when a nuclear fission reaction occurs can cause a chain reaction. A chain reaction can occur only if a critical mass of material is present.
- **3.** Nuclear fusion occurs at high temperatures when light nuclei collide and form heavier nuclei, releasing a large amount of energy.
- **4.** Radioactive tracers that are absorbed by specific organs can help diagnose health problems. Nuclear radiation is used to kill cancer cells.



FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review advantages and disadvantages of using radioactive materials and nuclear reactions.

# **Using Vocabulary**

alpha particle p. 791
beta particle p. 793
r
bubble chamber p. 797
chain reaction p. 802
cloud chamber p. 796
critical mass p. 802
gamma ray p. 793
Geiger counter p. 798

half-life p. 794 nuclear fission p. 801 nuclear fusion p. 803 radioactivity p. 788 strong force p. 787 tracer p. 804 transmutation p. 792

Use what you know about the vocabulary words to explain the differences in the following sets of words. Then explain how the words are related.

- 1. cloud chamber—bubble chamber
- 2. chain reaction—critical mass
- 3. nuclear fission—nuclear fusion
- 4. radioactivity—half-life
- **5.** alpha particle—beta particle—gamma ray
- **6.** Geiger counter—tracer
- 7. nuclear fission—transmutation
- 8. electroscope—Geiger counter
- 9. strong force—radioactivity

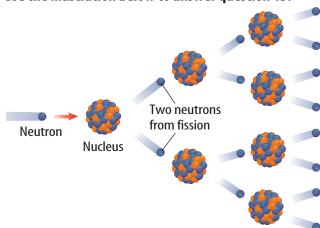
# **Checking Concepts**

Choose the word or phrase that best answers the question.

- **10.** What keeps particles in a nucleus together?
  - **A)** strong force
- **c)** electrical force
- **B)** repulsion
- **D)** atomic glue
- **11.** Which device would be most useful for measuring the amount of radiation in a nuclear laboratory?
  - A) a cloud chamber
  - **B)** a Geiger counter
  - c) an electroscope
  - **D)** a bubble chamber

- **12.** What is an electron that is produced when a neutron decays called?
  - A) an alpha particle
  - B) a beta particle
  - c) gamma radiation
  - **D)** a negatron
- **13.** Which of the following describes an isotope's half-life?
  - A) a constant time interval
  - **B)** a varied time interval
  - **c)** an increasing time interval
  - **D)** a decreasing time interval
- **14.** For which of the following could carbon-14 dating be used?
  - A) a bone fragment
  - B) a marble column
  - c) dinosaur fossils
  - D) rocks

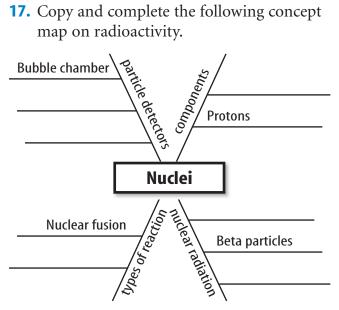
Use the illustration below to answer question 15.



- **15.** Which term describes an ongoing series of fission reactions such as the one pictured above?
  - A) chain reaction
- **c)** positron emission
- **B)** decay reaction
- **D)** fusion reaction
- **16.** Which of the following describes atoms with the same number of protons and a different number of neutrons?
  - **A)** unstable
- **C)** radioactive
- **B)** synthetic
- **D)** isotopes

# **Interpreting Graphics**

**17.** Copy and complete the following concept



**18.** Make a table summarizing the use of radioactive isotopes or nuclear radiation in the following applications: radioactive dating, monitoring the thyroid gland, and treating cancer. Include a description of the radioactive isotope or radiation involved.

Use the data in the table below to answer question 19.

Isotope Half-Lives						
Isotope	Mass Number	Half-Life				
Radon-222	222	4 days				
Thorium-234	234	24 days				
lodine-131	131	8 days				
Bismuth-210	210	5 days				
Polonium-210	210	138 days				

**19. Graph** the data in the table above with the *x*-axis the mass number and the *y*-axis the half-life. Infer from your graph whether there is a relationship between the half-life and the mass number. If so, how does half-life depend on mass number?

# **Thinking Critically**

- **20.** Explain why the amount of background radiation a person receives can vary greatly from place to place.
- **21.** Infer how the atomic number of a nucleus changes when the nucleus emits only gamma radiation.
- **22. Identify** the properties of alpha particles that make them harmful to living cells.
- 23. Determine the type of nuclear radiation that is emitted by each of the following nuclear reactions:
  - a. uranium-238 to thorium-234
  - **b.** boron-12 to carbon-12
  - c. cesium-130 to cesium-130
  - d. radium-226 to radon-222
- **24.** Determine how the motion of an alpha particle is affected when it passes between a positively charged electrode and a negatively charged electrode. How is the motion of a gamma ray affected?
- 25. Infer how the background radiation a person receives changes when they fly in a jet airliner.

# **Applying Math**

- **26.** Use a Ratio The mass of an alpha particle is 4.0026 mass units, and the mass of a beta particle is 0.000548 mass units. How many times larger is the mass of an alpha particle than the mass of a beta particle?
- **27.** Calculate Number of Half-Lives How many half-lives have elapsed when the amount of a radioactive isotope in a sample is reduced to 3.125 percent of the original amount in the sample.

# Standardized Test Practice chapter

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

# **Multiple Choice**

- **1.** If a radioactive material has a half-life of 10 years, what fraction of the material will remain after 30 years?
  - A. one-half
  - **B.** one-third
  - **c.** one-fourth
  - **D.** one-eighth
- **2.** Which of the following statements is true about all the isotopes of an element?
  - **A.** They have the same mass number.
  - **B.** They have different numbers of protons.
  - **C.** They have different numbers of neutrons.
  - **D.** They have the same number of neutrons.
- **3.** How does the beta decay of a nucleus cause the nucleus to change?
  - **A.** The number of protons increases.
  - **B.** The number of neutrons increases.
  - **c.** The number of protons decreases.
  - **D.** The number of protons plus the number of neutrons decreases.

#### Use the illustration below to answer question 4.





Helium-3

Helium-4

- **4.** Which is a true statement about the two nuclei?
  - **A.** They have the same atomic number.
  - **B.** They have the same mass number.
  - **C.** They have different numbers of electrons.
  - **D.** They have different numbers of protons.
  - **5.** What is the atomic number of a nucleus equal to?
    - **A.** the number of neutrons
    - **B.** the number of protons
    - **c.** the number of neutrons and protons
    - **D.** the number of neutrons minus the number of protons

#### Use the illustration below to answer questions 6 and 7.

<sup>210</sup><sub>84</sub>Po

<sup>4</sup>He











- **6.** What process is shown by this illustration?
  - **A.** nuclear fusion
  - **B.** chain reaction
  - **C.** transmutation
  - **D.** beta decay

#### **Test-Taking Tip**

**Understand the Question** Be sure you understand the guestion before you read the answer choices. Make special note of words like NOT or EXCEPT. Read and consider all the answer choices before you mark your answer sheet.

- **7.** How do the total charge and total mass number of the products compare to the charge and mass number of the polonium nucleus?
  - **A.** The charges are equal but the mass numbers are not equal.
  - **B.** The mass numbers are equal but the charges are not equal.
  - **c.** Neither the mass numbers or the charges are equal
  - **D.** The mass numbers and charges are equal.
- **8.** Radioactive isotopes of which element are used to study the brain?
  - A. uranium
  - **B.** fluorine
  - c. carbon
  - **D.** lead

# Gridded Response

Use the table below to answer questions 9 and 10.

Half-Lives of Isotopes				
Isotope	Half-life			
Carbon-14	5,730 years			
Potassium-40	1.28 billion years			
lodine-131	8.04 days			
Radon-222	4 days			

**9.** How many grams of an 80-g sample of carbon-14 will be left after 17,190 years?

# Short Response

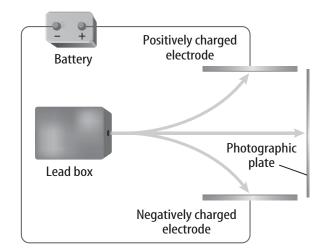
**10.** A sample containing which radioactive isotope will have one-eighth of the isotope left after 24 days?

**11.** When the boron isotope boron-10 is bombarded with neutrons, it absorbs a neutron and then emits an alpha particle. Identify the isotope that is formed in this process.

#### **Extended Response**

**12.** Compare the strength of the strong force and the strength of the electric force on a proton in a small nucleus and in a large nucleus.

Use the illustration below to answer question 13.



- **13.** In the figure above, nuclear radiation is escaping from a small hole in the lead box.
  - **PART A** Which type of nuclear radiation is deflected toward the positivelycharged electrode, and why is this radiation deflected toward this electrode?
  - **PART B** Explain why the radiation that struck the photographic plate was not deflected by the electrodes.

# chapter

# 26

#### BIG (Idea

The gravitational contraction of enormous clouds of gas forms stars and galaxies.

# 26.1 Observing the Universe

MAIN (Idea Telescopes form clear images of distant objects by collecting the light they emit.

# 26.2 Evolution of Stars

MAIN (Idea) The life cycle of a star depends on its mass.

# 26.3 Galaxies and the Milky Way

MAIN (Idea Galaxies have different sizes and are classified into three main groups.

# 26.4 Cosmology

MAIN (Idea) The universe has been expanding for billions of years.

# Colliding Galaxies

These two objects are spiral galaxies that are colliding. When galaxies collide, they actually pass through each other. However, gravitational forces cause the galaxies to change shape and possibly merge. Eventually these two galaxies will merge into one giant galaxy.

#### **Science Journal**

In your Science Journal, compare and contrast the stars you see at night with the Sun.



# **Start-Up Activities**



# Stars in the Sky

Have you ever looked up at the night sky and been amazed at the number of stars you could see? But if you live in a well lighted area, you may not have seen very many stars at all. In this lab, you will explore a quick way to estimate how many stars you can see in different parts of the sky.

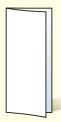
- 1. Ask an adult to help you locate an area near your home suitable for star gazing where there are not very many lights.
- 2. Hold a cardboard tube up to one eye and look through it at one area of the sky.
- 3. Count the number of stars you can see easily through the tube.
- 4. Look at three other areas of the sky in the same way and count those stars. Try looking to the south, west, straight up, and in a random direction.
- 5. Compare your data with those of two or three other students.
- **6. Think Critically** In your Science Journal, report whether a similar number of stars were easily visible no matter where you looked or whether the number of stars varied. Explain any similarities or differences noted by you or other students.

# FOLDABLES" **Study Organizer**

**Cosmology** Make the following Foldable to help identify what you know, what

you want to know, and what you learned about stars, galaxies, and cosmology.

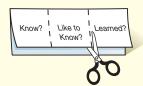
**STEP 1 Fold** a vertical sheet of paper from side to side. Make the front edge about  $\frac{1}{2}$  inch longer than the back edae.



**STEP 2 Turn** lengthwise and fold into thirds.



STEP 3 **Unfold and cut** only the top layer along both folds to make three tabs. Label each tab as shown.



**Questioning** Before you read the chapter, write what you know about cosmology under the left tab of your Foldable, and write questions about what you'd like to know under the center tab. After you read the chapter, list what you learned under the right tab.



Preview this chapter's content and activities at qpescience.com

# 1

# **Observing the Universe**

# Reading Guide

## What You'll Learn

- Describe a constellation as a pattern of stars.
- Compare and contrast types of optical telescopes.
- **Explain** how a radio telescope differs from an optical one.

# Why It's Important

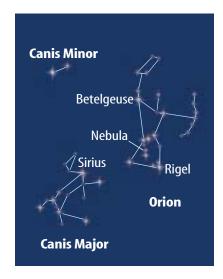
You can observe different parts of the universe from your home.

## Review Vocabulary

**electromagnetic spectrum:** the entire range of wavelengths of electromagnetic energy

#### **New Vocabulary**

- constellation
- refracting telescope
- reflecting telescope
- radio telescope
- light-year
- spectroscope



**Figure 1** These three constellations contain some of the brightest stars visible from the northern hemisphere—Betelgeuse, Rigel, and Sirius.

# **Constellations**

Have you ever watched clouds drift by on a summer day and tried to find shapes and patterns in them? One might look like a ship and another might resemble a rabbit or a bear. Long ago, people did much the same thing with stars. They named these patterns of stars after characters in stories, animals, or tools. Many of the names given to these star patterns by ancient cultures survive today and are called **constellations**. Astronomers use these constellations to locate and name stars.

From Earth, the stars in a constellation appear relatively close to one another. You can see that some of the stars are brighter than others, but you can't see how far they are from you or from each other. Usually, they lie at greatly different distances from Earth and just happen to line up and form a pattern.

In **Figure 1**, three constellations are shown with some of their brighter stars. The constellations visible in the evening sky change throughout the year.



**Mythology** In many cultures, Orion was a great hunter who had two hunting dogs,

Canis Major (big dog) and Canis Minor (little dog). In another myth, two bears traveled around Earth's north pole. The constellations Ursa Major and Ursa Minor (big and little bears) were named for them. Indeed, they do swing around the north pole. In fact, Polaris, the polestar, is in Ursa Minor. If you have seen the Big Dipper you have seen most of Ursa Major, because the dipper is part of this constellation.

**Telescopes** Constellations and the stars that make them up are visible with the unaided eye. However, to see other objects in space, you need a telescope. Scientists and amateur astronomers use many different types of telescopes. Optical telescopes are used to study objects by detecting the visible light they reflect or emit. Radio telescopes are used to study objects by detecting radio waves coming from the objects.

**Optical Telescopes** Optical telescopes collect much more light from distant objects than can enter the unaided human eye. As a result, images produced by optical telescopes are brighter and clearer. There are two types of optical telescopes. One type uses a lens called an objective lens to collect light. The other type uses a curved mirror called the objective mirror. Both an objective lens and an objective mirror form an image of a distant object at a point called the focal point. The image at the focal point is then magnified by an eyepiece lens.

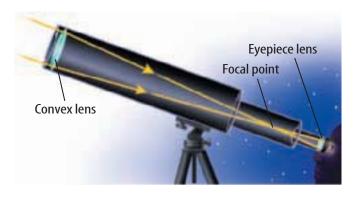
The distance from a lens or a mirror to its focal point is called the focal length. The magnifying power  $(M_p)$  of a telescope is equal to the focal length of the objective lens or mirror  $(f_0)$  divided by the focal length of the eyepiece lens  $(f_e)$ :

$$M_{\rm p} = f_{\rm o}/f_{\rm e}$$

**Refracting Optical Telescopes** A **refracting telescope** uses a convex lens, which is curved outward like the surface of a ball, to collect light, as shown in **Figure 2.** Light passes through the objective lens and the eyepiece lens then magnifies the image. There is a limit to how large a refracting telescope can be. Since the objective lens can be supported only at its edges, it could sag in the middle if it is too large. Then the image formed by the lens is blurred. As a result, the largest refracting telescope ever built has an objective lens that is about one meter in diameter.



What type of optical telescope uses a lens to collect light?





#### **Modeling a Telescope**

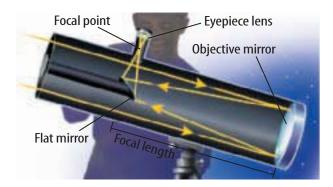
#### Procedure m

- Obtain two lenses of different focal length from your teacher.
- **2.** Place **double-sided tape** around the edge of one lens.
- 3. Place the lens along the short side of a piece of construction paper and roll the paper around the lens to form a tube. Tape the tube securely.
- **4.** Repeat steps 2 and 3 with the other lens.
- 5. Insert the small tube into the large tube with the lenses on opposite ends.
- **6.** Look through the eyepiece lens (small tube) and slide it in and out until you see a clear image.

#### **Analysis**

- Observe an object with and without your telescope.
   Estimate how many times larger it appears through the telescope.
- 2. Obtain the focal lengths of your lenses from your teacher. Calculate the magnifying power of your telescope using the equation on this page. Compare this value to your estimate.

**Figure 2** A refracting telescope uses a convex lens to collect light and form an image at the focal point. This image is then magnified by the eyepiece lens.



**Figure 3** Reflecting telescopes use concave mirrors to gather light.

Reflecting Optical Telescopes A reflecting telescope uses a mirror to collect light. Figure 3 shows how light passes through the open end of a reflecting telescope and strikes a concave mirror. Often, a smaller mirror is used to reflect light into the eyepiece. However, in very large reflecting telescopes, the astronomer sits inside the telescope and looks through the eyepiece at the image. Because mirrors can be supported on their back surface, reflecting telescopes with mirrors several meters in diameter can be built.

# **Applying Math**

### **Use Equations**

**THE MAGNIFYING POWER OF TELESCOPES** If the focal lengths of a telescope's objective and eyepiece are known, the magnifying power can be calculated from the equation:

$$M_{\rm p} = f_{\rm o}/f_{\rm e}$$

In this equation,  $M_{\rm p}$  is the magnifying power of the telescope,  $f_{\rm o}$  is the focal length of the objective, and  $f_{\rm e}$  is the focal length of the eyepiece. Find the magnifying power of a telescope with a focal length of 1200 mm using eyepieces of 20 mm and 6 mm.

#### **IDENTIFY** known values and unknown values.

Identify the known values.

the focal length of the objective is 1,200 mm, this  $f_0 = 1,200$  mm

the focal lengths of the eyepieces are 20 mm and 6 mm, this  $f_e = 20$  mm; 6 mm

Identify the unknown value

what is the magnifying power of the telescope  $M_p = ?$ 

#### SOLVE the problem

Substitute the known values into the equation for magnifying power:

$$M_{\rm p} = 1,200 \text{ mm/20 mm} = 60$$
  $M_{\rm p} = 1,200 \text{ mm/6 mm} = 200$ 

Notice that the units cancel, and that magnifying power has no unit.

#### CHECK the answer

Does your answer seem reasonable? Do images look 60 times larger than the object when using the 20 mm eyepiece and 200 times larger when using the 6 mm eyepiece?

#### **Practice Problems**

- **1.** Find the magnifying power of a telescope with a focal length of 2,500 mm when using eyepieces with focal lengths of 50 mm and 10 mm.
- **2.** Find the magnifying power for a telescope with a focal length of 900 mm when using an eyepiece with a focal length of 12 mm.

For more practice problems, go to page 879 and visit Math Practice at gpescience.com.

Adaptive Optics If you look at the sky at night, you will notice that the stars seem to twinkle. The twinkling of stars is caused by temperature variations and air currents in Earth's atmosphere. The twinkling effect blurs the images produced by telescopes on Earth. Some telescopes use a system called adaptive optics to make images sharper. In an adaptive optics system, the light from the objective mirror strikes a small, deformable mirror before it is focused. A sensor samples the light from the objective mirror to determine how distorted the images are. The surface of the deformable mirror is then

adjusted many times a second to reduce the constantly changing distortion.

**Radio Telescopes** Radio waves, like visible light, are a form of electromagnetic radiation emitted by stars and other objects. Radio waves can be detected even during the day, when the Sun's light makes it impossible to see the fainter visible light from other stars. Radio waves pass through Earth's atmosphere, even on completely cloudy days. A **radio telescope** collects and amplifies radio waves. The radio waves are collected by a large dish that is usually tens of meters or more in diameter. The dish focuses the radio waves, just like the objective mirror in a reflecting telescope. **Figure 4** shows the radio telescopes that are part of the Very Large Array (VLA) near Socorro, New Mexico.



What type of telescope is used to study radio waves?

**Space Telescopes** There is another way of avoiding the blurring effects of Earth's atmosphere on optical images. That is to place a telescope in space above the atmosphere. In 1990 the

**Figure 5,** was placed in orbit around Earth by the Space Shuttle. Because of its location above the atmosphere, the *HST* has obtained clearer images than those obtained by most ground-based telescopes. The atmosphere also absorbs other types of electromagnetic radiation, such as ultraviolet waves and X rays as well as some types of infrared radiation. Some space telescopes now orbiting Earth, such as the *Chandra X-Ray Observatory* and the *Spitzer Space Telescope*, collect data using wavelengths that are absorbed by the atmosphere.



**Figure 4** The VLA has 27 radio telescopes, each with a dish that is 25 m in diameter.

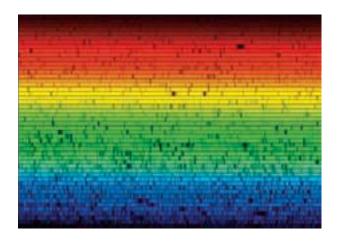


Visit **gpescience.com** for Web links to information about the development of new telescopes.

**Activity** Write and illustrate a paragraph about one of the new designs being considered for Earth-based telescopes or Earth-orbital telescopes.

**Figure 5** The *Hubble Space Telescope* orbits Earth at an altitude of 610 km.





**Figure 6** The dark lines in stellar spectra tell astronomers what elements are present in the stars being studied.

**Explain** how a spectroscope produces a spectrum of colors.

# **Spectroscopes**

The light from stars and other objects can provide information about the star's composition, its temperature, and even how fast it's moving toward or away from Earth. The light emitted from objects in space is made of different wavelengths of visible light. The wavelengths emitted by a star, for example, depend on the star's temperature and composition. Astronomers use a spectroscope to analyze the different wavelengths in light collected by optical telescopes. A **spectroscope** is a device that uses a prism or dif-

fraction grating to separate light into its component wavelengths. The separated wavelengths are called the spectrum of the star. **Figure 6** shows a spectrum from a star produced by a spectroscope.



Reading Check What does a spectroscope do?

**The Light-Year** The fastest thing in the universe is light, which travels at a speed of about 300,000 km/s in space. Large telescopes can see objects so far away that it takes millions or billions of years for light from these objects to reach Earth. To measure these enormous distances, astronomers use a unit called the light-year. A light-year is the distance light travels in one year. A light-year is about 9.5 trillion kilometers.

# section

# review

# **Summary**

#### **Constellations**

 Constellations are patterns of stars that are used today to name and locate stars.

#### **Telescopes**

- Refracting telescopes use lenses to collect light and magnify the image.
- Reflecting telescopes use a mirror to collect light and a lens to magnify the image.
- A radio telescope collects and amplifies radio waves.

#### **Spectroscopes**

 A spectroscope disperses light into its spectrum.

#### **Self Check**

- 1. **Define** constellation.
- 2. Compare and contrast refracting telescopes and reflecting telescopes.
- 3. Explain why the largest telescopes are reflecting telescopes and not refracting telescopes.
- **4. Explain** why telescopes are placed in orbit.
- 5. Think Critically What would be an advantage of building a telescope on a high mountain?

#### **Applying Math**

**6.** Use Numbers If the magnifying powers (M<sub>n</sub>) of refracting and reflecting telescopes are 20 and 100, respectively, how much greater is the M<sub>n</sub> of the reflecting telescope?

# **Evolution of Stars**

# **Reading Guide**

# *What* You'll Learn

- **Explain** how stars form.
- **Classify** the stages of stellar evolution using a Hertzsprung-Russell (H-R) diagram.
- **Describe** the Sun and explain how it has and will evolve.

# Why It's Important

The Sun is the star that provides energy for life on Earth.

# Review Vocabulary

nuclear fusion: a nuclear reaction in which atomic nuclei join together.

### **New Vocabulary**

- main sequence
- giant
- white dwarf
- photosphere
- sunspots

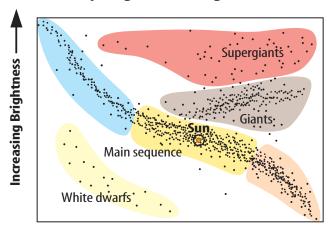
# **How do stars form?**

Star formation begins with a large cloud of gas, ice, and dust called a nebula. These particles exert an attractive gravitational force on each other, causing the nebula to contract. Forces within the nebula cause it to break up into smaller cloud fragments. As a cloud fragment continues to contract, its temperature increases. A protostar forms at the center of the cloud when the temperature there reaches 1 million K. When the temperature of the protostar reaches 10 million K, the nuclear fusion of hydrogen into helium begins. Then a star is born.

H-R Diagram In the early 1900s, Einjar Hertzsprung and Henry Russell found that stars with higher temperatures usually radiated more energy and were brighter. The relationship between the brightness and temperature of stars can be shown on a Hertzsprung-Russell diagram, like the one in **Figure 7.** When the brightness and temperature of stars are plotted on a H-R diagram, about 90 percent of all stars fall on a region called the main sequence. The main sequence goes from the upper left to the lower right on an H-R diagram. Other types of stars generally fall into three other regions of the H-R diagram.

**Figure 7** A star's brightness and temperature are plotted on an H-R diagram. Most stars fall on the main sequence. Supergiants, giants, and white dwarfs fall into different parts of the H-R diagram.

# **Hertzsprung-Russell Diagram for Stars**



**Decreasing Temperature** 



#### **Counting Stars**

#### Procedure <

- 1. Draw a grid of twenty squares, with each square measuring 5 cm on a side. The final grid will be 25 cm long and 20 cm wide.
- 2. Randomly scatter about one tablespoon of white rice over the grid.
- 3. Select three squares and count the number of rice grains that are either completely within each square or partly touching its right side or bottom. Calculate the average number in each square.
- **4.** Multiply the average by 20.

#### **Analysis**

- 1. How many rice grains are located within the grid?
- 2. How does this process model counting stars?

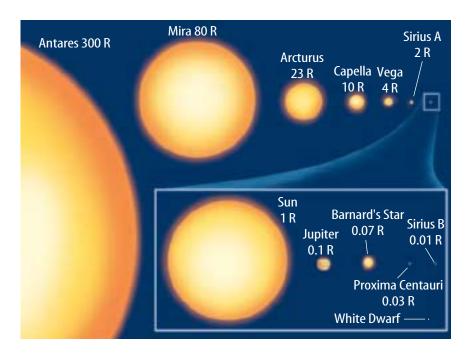
# **How do stars change?**

The protostar formed in the center of a cloud fragment continues to collapse until nuclear fusion begins. Then the radiation emitted by the fusion reactions exerts an outward pressure on the material in the star. Meanwhile, the gravitational forces in the star continue to pull material inward toward the star's center. Equilibrium is reached when the outward pressure exerted by the emitted radiation balances the inward pull of gravity. When these forces are balanced, the star stops shrinking.

**Main Sequence** Once equilibrium is reached, the star becomes a main sequence star. As long as the star is in equilibrium, the star remains on the main sequence. Most stars are main sequence stars for most of their lifetimes. The Sun has been a main sequence star for about five billion years and will continue to be a main sequence star for another five billion years.

Reading Check The Sun is classified as which type of star?

When a star finally uses up all the hydrogen in its core, it is no longer in equilibrium. The star then enters a new stage in its development. What happens to the star depends on its mass. A star of average mass, such as the Sun, will become a red giant, then a white dwarf, and finally a black dwarf. Stars more massive than the Sun can become supergiants and end up as neutron stars or black holes. Stars much lower in mass than the Sun could remain on the main sequence as red dwarfs for 16 trillion years. Most stars on the main sequence are red dwarfs, and they probably make up about 80 percent of all stars.



**Figure 8** Only part of the giant star Antares is shown here. Super giant stars, such as Betelgeuse, are too large to be shown at all.

**Giants and Dwarfs** When hydrogen in a star's core is used up, the outward radiation pressure becomes less than the inward pull of gravity. Its core contracts and increases in temperature. The outer layers expand and cool. In this late stage of its life cycle, the star has become a **giant.** In about five billion years, our Sun will become a giant like the one shown in **Figure 8.** 

The giant's core continues to contract and become hotter. Eventually, the core uses up its helium and contracts even more. When the core temperature reaches 100 million K, helium fuses, forming carbon. Now the star is enormous and its surface is much cooler. Its outer layers escape into space leaving behind the hot, dense core that continues to contract. At this final stage in an average star's evolution, it is a white dwarf. A white dwarf, also shown in **Figure 8**, is about the size of Earth.

Supergiants, Neutron Stars, and Black Holes Stars that are over eight times more massive than our Sun develop in a different way. Their cores reach temperatures high enough to cause fusion that produces heavier and heavier elements. The star expands into a supergiant, such as Betelgeuse shown in **Figure 9.** Eventually, nuclear fusion stops when iron accumulates in the core. Then, there is no outward radiation pressure to counteract the inward pull of gravity. The core collapses violently, and the outer portion of the star explodes, producing a supernova.

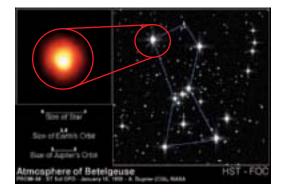
A supernova is a gigantic explosion in which the temperature in the collapsing core reaches 10 billion K and atomic nuclei are split into neutrons and protons. Protons merge with electrons to form neutrons, and the collapsing core becomes a neutron star. A typical neutron star is the size of a major city on Earth, but has a mass greater than the Sun's.

Very massive stars, with masses greater than 25 times that of the Sun, face a different end. In this case, the final collapse of the core continues past the neutron-star stage, forming a black hole—an object so dense that nothing can escape its gravity if it gets too close.

**Supernovas** A supernova explosion can emit so much energy that for a short time it can be brighter than an entire galaxy. The nuclear fusion reactions that occur inside various stars produce chemical elements from helium to iron on the periodic table. Elements with atomic numbers higher than iron are produced during a supernova explosion. The supernova explosion blasts all these elements into interstellar space. The elements from supernovas form solar systems, planets, and all living things on Earth, including you.

**Figure 9** Betelgeuse is located in the constellation of Orion. Its diameter is larger than the diameter of Jupiter's orbit around the Sun.

**Classify** What kind of star is Betelgeuse?



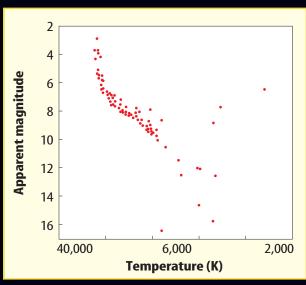
# NATIONAL VISUALIZING H-R DIAGRAMS GEOGRAPHIC OF STAR CLUSTERS

### Figure 10

he Pleiades star cluster blazed into existence a mere 100 million years ago, when dinosaurs reigned on Earth and mammals were just gaining a foothold. The Pleiades, located in the back of the constellation Taurus, is among the earliest of celestial objects to be known and recorded by humans. Many myths sprang up to explain their origin. Today, astronomers study star clusters like the Pleiades because they offer valuable insights into how the universe is evolving.

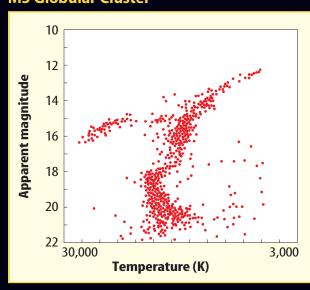


#### **Pleiades**



Because star clusters are believed to have formed from the same nebula, they are assumed to be about the same distance away. For this reason they are plotted using apparent magnitude instead of absolute magnitude or luminosity. Note that a lower magnitude number represents a brighter star. The H-R diagram for the Pleiades shows a well-defined main sequence. Stars in the upper left are hot, blue, and massive. As stars age, they burn all available hydrogen and eventually become red giants. The presence of hot, blue stars and the lack of red giants indicate that the Pleiades is a relatively young star cluster.

#### **M5 Globular Cluster**



M5 is a globular cluster, located roughly 24,500 light-years from Earth. It has a compact appearance and vastly more stars than are found in open clusters like the Pleiades. Astronomers believe M5 is

one of the oldest star clusters in our galaxy, with an estimated age of 13 billion years.

Compare the H-R diagram for M5 to the H-R diagram for the Pleiades. The stars in cluster M5, which were once hot and blue, have evolved into cooler, highly luminous red giants that appear in the upper right of the diagram. Sun-sized stars evolve from main sequence to red giants over billions of years, indicating that M5 is an ancient star cluster.

# The Sun—A Main Sequence Star

Although the Sun is an average star, it is by far the largest object in the solar system. The Sun is about 1.4 million kilometers in diameter—about 109 times larger than Earth and even 10 times larger than Jupiter. Like all stars, the Sun is made almost entirely of hydrogen and helium. About 70 percent of the Sun's mass is hydrogen and about 28 percent is helium. Much of the remaining 2 percent of the Sun's mass is oxygen and carbon. The Sun contains about 99 percent of all the mass in the solar system.

**Structure of the Sun** The Sun can be divided into several distinct layers or zones—the core, the radiation zone, and the convective zone. These zones are shown in **Figure 11.** The visible surface of the Sun that you see is the **photosphere**. The photosphere is the layer that emits light into space. The temperature of the photosphere is about 5,800 K. Outside of the photosphere, the Sun has an atmosphere that is divided into two layers. The inner layer of the atmosphere is the chromosphere, and the outer layer is the corona.

**The Core** The core extends from the center of the Sun to about 140,000 km from the center. Nuclear fusion occurs in the Sun's core, producing the energy that reaches Earth. The fusion reactions change hydrogen nuclei into helium nuclei. The temperature in the core is about 15 million K—so high that atoms have been stripped of their electrons. As a result, the core is a gas made of charged particles. The state of matter made of charged particles is a plasma.

**The Radiation Zone** Above the core is the radiation zone, extending from about 140,000 km to about 500,000 km from the center. Here temperatures are still so high that matter is in the plasma state. In the radiation zone, the energy produced by nuclear fusion is transferred from the core by electromagnetic radiation. The temperature of the radiation zone decreases with distance from the core from about 7 million K to about 2 million K at the top of the radiation zone.

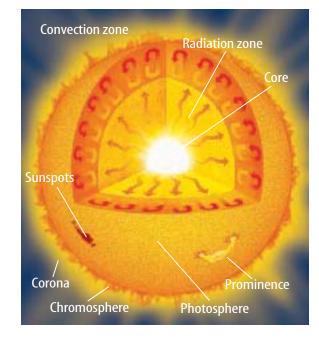
**The Convection Zone** The Sun's outer layer is the convection zone. Here energy is transferred from the top of the radiation zone to the surface by thermal convection. Columns of hot material form convection cells as they rise to the surface, cool, and then sink back to the bottom of the convection zone.

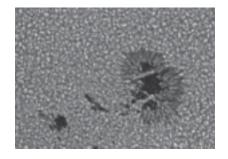


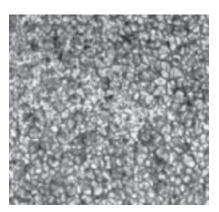
Energy for Life Plants use energy from the Sun and produce carbohydrates in a process called photosynthesis. When we burn fossil fuels, such as coal, we are using energy from the Sun that is stored in fossilized plant materials. Scientists also are trying to make direct use of solar energy by using solar cells. Research some applications of solar energy and share your results with your class.

**Figure 11** The Sun's interior is divided into three parts: the core, the radiation zone, and the convection zone.

**List** three of the Sun's layers, starting with the surface and moving outward.

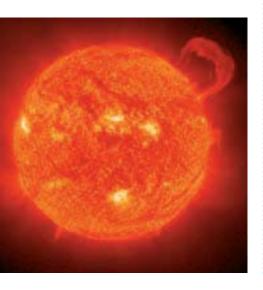






**Figure 12** Sunspots, above, are often 2,000 K cooler than the surrounding granules, shown below.

**Figure 13** This prominence of dense plasma appears suspended in the Sun's chromosphere as it loops back to the surface.



**Photosphere** The sun's photosphere is at the top of the convection zone. The photosphere has a grainy appearance, as shown in **Figure 12.** The individual grains are called granules and are typically about 1,000 km across. Granules are the tops of the convection cells. The bright areas are hot material that is rising and the dark areas are cooler material that is sinking.

**Sunspots** Some areas of the Sun appear darker than others. These darker areas of the Sun's photosphere, called sunspots, are cooler than surrounding areas. The top photo of **Figure 12** shows a closeup view of a sunspot. Temperatures in the dark center of sunspots can be 2,000 K cooler than the surrounding granules. Sunspots are carried along by the Sun's rotation. The movement of sunspots shows that the Sun rotates faster at its equator than at its poles. Sunspots are caused by regions of strong magnetic fields that reduce the transport of energy to the surface by convection.

Reading Check What is a sunspot?

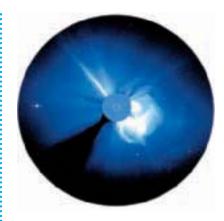
Sunspots aren't permanent features of the Sun. They appear and disappear over periods of days, weeks, or months. The number of sunspots changes in a fairly regular pattern called the sunspot, or solar activity, cycle. Periods of sunspot maximum occur about every 11 years, with periods of sunspot minimum occurring in between. At a sunspot minimum, sunspots appear at high latitudes. As the cycle progresses, they appear closer to the Sun's equator. By the next minimum, they again cluster at high latitudes.

**Prominences and Flares** Intense magnetic fields associated with sunspots can cause huge arching columns of gas called prominences to erupt, as shown in **Figure 13**. Convection in the convection zone causes magnetized gases to flow upward toward the photosphere. Sometimes the magnetic field strength is great enough that magnetic field lines shoot out from the surface near a pair of sunspots and cause a prominence of solar material to loop from one spot to the other. Some prominences blast material from the sun into space at speeds ranging from 600 km/s to more than 1,000 km/s.

Gases near a sunspot sometimes brighten suddenly, shooting gas outward at high speed in what are called solar flares. Temperatures within these flares can reach 100 million K. Particles produced in a flare possess so much energy that the Sun's magnetic field cannot hold them as it can hold prominences, and they blast into space.

**CMEs** Sometimes large bubbles of ionized gas are emitted from the Sun. These are known as CMEs (coronal mass ejections). During sunspot minimums there is usually one CME per week, but during a sunspot maximum, there are two to three per day. When a CME is released in the direction of Earth, it appears as a halo around the Sun, as shown in **Figure 14.** As it passes Earth, the planet is exposed to a sudden shock wave of increased solar wind. Earth's atmosphere protects us, but occurrences of auroras increase. When scientists note a CME, they post an alert to watch for auroras at lower latitudes than normal.

Auroras take place when high-energy particles in CMEs and the solar wind are carried past Earth's magnetic field. This generates large electric currents that flow toward Earth's poles. These electric currents ionize gases in Earth's atmosphere. When these ions recombine with electrons and drop to a lower energy level, they produce light. This light is called the aurora borealis, or northern lights, when it occurs in the northern hemisphere. In the southern hemisphere, it is called the aurora australis. CMEs present little danger to life on Earth, but some of the highly charged solar wind material disrupts Earth's magnetosphere and interferes with orbiting satellites and radio signals.



**Figure 14** CMEs like this one can hurl a million tons of matter into space each second. They can damage satellites and endanger astronauts.

#### review section

### **Summary**

#### How do stars form?

- Stars form from a large cloud of gas, ice, and dust. Once the temperature inside the nebula reaches 10 million K, fusion begins.
- The H-R diagram shows how temperature and brightness of stars are related.

#### How do stars change?

- Once fusion begins, a star develops stellar equilibrium and becomes a main sequence star.
- When the hydrogen fuel is depleted, a star loses stellar equilibrium and evolves into a giant, or a supergiant.

#### The Sun—A Main Sequence Star

- The Sun's energy is produced by fusion.
- Sunspots are dark, cooler regions on the Sun's photosphere.
- Other solar features that can affect Earth are prominences, flares, and CMEs.

#### **Self Check**

- 1. Explain how stars form from nebulae.
- **2. Describe** the different evolution stages of stars as shown on the H-R diagram.
- **3. Describe** the structure of the Sun.
- **4. Explain** how the radiation zone is different from the convection zone in the Sun.
- 5. Think Critically What happens to stellar equilibrium to make a main sequence star evolve into a giant star?

## **Applying Math**

- **6. Use Percentages** Eighty percent of all stars are red dwarfs. Out of a random sample of 2,000 stars in the galaxy, about how many will plot on the H-R diagram as a red dwarf?
- **7. Use Numbers** If the Sun will remain a main sequence star for a total of 10 billion years and Proxima Centauri will remain one for 16 trillion years, how many times longer will Proxima Centauri be a main sequence star?



# Stir Cluster Age

Stars are plotted on the H-R diagram based on their temperature and brightness. You can determine the age of a cluster of stars by studying the H-R diagram of the stars within the cluster. Massive main sequence stars, located at the upper left of the diagram, evolve faster than stars farther down the main sequence. Stars in the lower right of the diagram evolve more slowly. How could you use this idea to help determine the relative ages of star clusters from their H-R diagrams?

uminosity solar units

Spectral type

the relative ages of the other two star clusters. *HINT: The oldest cluster will have* 

some stars that have evolved to white dwarfs.

# Real-World Problem

How can the relative age of star clusters be determined from H-R diagrams of each cluster?

#### Goals

- Compare and contrast H-R diagrams of several star clusters.
- **Determine** the relative ages of four star clusters.

#### **Materials**

four H-R diagrams of star clusters

# Procedure

- Study the four H-R diagrams your teacher gives you.
- 2. Note which types of stars remain on the main sequence and which stars have evolved off the main sequence.
- Based on the evolution of the stars within each star cluster, decide which cluster is youngest and which is oldest. Also decide

# Conclude and Apply

- Compare and contrast H-R diagrams of four star clusters.
- **2. Determine** which star cluster was youngest and which was oldest.
- **3. Explain** how you determined the ages of these two star clusters.
- **4. Determine** the relative ages of the remaining two star clusters.
- **5. Explain** how you determined the ages of these two star clusters.

# Communicating Your Data

**Explain** to your friends how the relative ages of star clusters can be found by studying H-R diagrams.

# **Galaxies and the Milky Way**

# **Reading Guide**

# *What* You'll Learn

- **Explain** that the same natural laws that apply in the Milky Way Galaxy also apply in other galaxies.
- **Compare** the three main types of galaxies.
- **Describe** the Milky Way galaxy and the Sun's position in it.

# Why It's Important

The Milky Way galaxy is your galaxy and you can see part of it stretching across the evening sky.

# Review Vocabulary

ellipse: oval-shaped, closed curve

### **New Vocabulary**

- galaxy
- Milky Way
- Local Group

# **Galaxies**

On a clear night, away from bright lights, you might be able to see thousands of stars. One faint speck you might be able to see in the constellation Andromeda is not a star at all. Instead, it is a group of billions of stars called the Andromeda Galaxy. A galaxy is a large group of stars, dust, and gas held together by gravity. An example of a galaxy is shown in **Figure 15.** 

The Sun is part of a galaxy called the Milky Way. The stars you see in the night sky are also part of the Milky Way. The Milky Way contains between 200 billion and 400 billion stars. The Andromeda Galaxy, which is the closest large galaxy, might contain as many as a trillion stars. Recall that the distances between stars are so large that they are measured in light-years. Distances between galaxies are much larger. For example, the distance between the Milky Way and the Andromeda Galaxy is about 2.5 million light-years. Galaxies also have different shapes. Based on their shapes, galaxies are classified into three groups—spiral galaxies, elliptical galaxies, and irregular galaxies.

**Spiral Galaxies** The galaxy shown in **Figure 15** is an example of a spiral galaxy. Spiral galaxies are disk-shaped and usually have arms that wind outward from the galaxy's center. These spiral arms are star-forming regions and contain clouds of dust and gas. Spiral galaxies also have a central bulge, or nucleus, where stars are closer together. The sizes of spiral galaxies typically range from about 20,000 to 200,000 light years. Both the Milky Way and the Andromeda Galaxy are spiral galaxies.

**Figure 15** This spiral galaxy is called the Pinwheel Galaxy and is about 25 million light-years away. **Explain** what is meant by a million light-years.





**Figure 16** This image was taken with the *Hubble Space Telescope* and show the giant elliptical galaxy ESO 325-G004. This galaxy is more than 450 million light-years from Earth and contains several hundred billion stars. The bright crosses are images of nearby stars and are not part of the galaxy.

**Figure 17** This image shows the dwarf irregular galaxy NGC 4449. This galaxy is about 20,000 light-years across and is about 12 million light-years away.

Elliptical Galaxies Unlike spiral galaxies, elliptical galaxies are not flat disks with spiral arms. Instead, elliptical galaxies are round and have shapes that range from nearly spherical to football-shaped. **Figure 16** shows an elliptical galaxy. Elliptical galaxies contain less dust and gas than spiral galaxies. As a result, there is less star formation than in spiral galaxies, so that elliptical galaxies contain mainly older stars.

Elliptical galaxies have a much larger range of sizes than spiral galaxies. The largest galaxies are elliptical galaxies. The largest elliptical galaxies might contain over 10 trillion stars and can be over 1 million light-years in size. The smallest elliptical galaxies are called dwarf ellipticals and can be only a few thousand lightyears in diameter. Dwarf elliptical galaxies usually contain less than 10 million stars.

**Irregular Galaxies** Galaxies that don't have an elliptical or spiral shape are classified as irregular galaxies. Irregular galaxies, such as the one shown in **Figure 17**, are usually larger than dwarf elliptical galaxies but smaller than spiral galaxies. Their sizes range from about 3,000 light-years to 30,000 light-years, and they can contain between 100 million to 10 billion stars. The smallest irregular galaxies are called dwarf irregular galaxies. Irregular galaxies might be the most common type of galaxy. Most irregular galaxies contain a high percentage of young stars, along with large amounts of gas and dust.

Two of the closest galaxies to the Milky Way are the Large Magellanic Cloud (LMC) and the Small Magellanic Cloud (SMC). Both are small, irregular galaxies that orbit the Milky Way at a distance of about 200,000 light-years.

**The Local Group** Just as stars group together to form galaxies, galaxies also form groups. The Milky Way is part of a group of galaxies called the Local Group. The Local Group is spread over about a region of about 10 million light-years in diameter



and includes about 50 galaxies. Most of these galaxies are dwarf elliptical galaxies and dwarf irregular galaxies. There are only three spiral galaxies in the Local Group, including the Milky Way galaxy and the Andromeda Galaxy. These two galaxies are the largest galaxies in the Local Group. Many of the dwarf and irregular galaxies in the Local Group orbit the Milky Way or the Andromeda Galaxy.

# How do galaxies form?

Astronomers hypothesize that the first galaxies began to form about 14 billion years ago as enormous clouds of gas began to collapse. These clouds of gas were much larger than the gas clouds from which stars form. As the galactic gas cloud contracted, smaller regions formed where the density of gas was even higher. Stars then formed in these higher-density regions.

The first galaxies that formed tended to be irregular galaxies and were generally smaller than galaxies are now. The first galaxies also tended to be closer together. Astronomers think that many of the galaxies seen today were formed when these first galaxies collided or merged with each other.

Interactions Between Galaxies When galaxies are close to each other, the gravitational forces between the galaxies can change their shapes. For example, some irregular galaxies might have been formed by the gravitational interactions between galaxies. The galaxies might have passed close enough to each other for a large group of stars to be ripped away from one of the galaxies. Also, when galaxies pass close to each other, gravitational forces between the galaxies can cause them to merge. For example, large elliptical galaxies can form when two or more spiral galaxies merge. However, spiral galaxies don't change shape when they merge with much smaller galaxies.

Reading Check What force causes galaxies to merge?

Figure 18 shows two large spiral galaxies that are merging. Here the centers of the two galaxies are about 100,000 light-years apart. These galaxies have been moving toward each other for about 40 million years. The gravitational forces the two galaxies exert on each other have begun to distort their shapes. The two galaxies will move around each other for billions of years. Gradually, they will merge to form a larger single galaxy without any spiral structure. You might think that some of the stars in these galaxies are colliding with each other. However, stars in galaxies are so far apart that when galaxies collide, the stars just move past each other.

**Figure 18** These two galaxies are passing close enough to cause them to begin to merge.

Gravitational forces between the galaxies have started to distort their shapes. These galaxies are about 114 million light years away.





#### **Topic: The Milky Way Galaxy**

Visit gpescience.com for Web links to information about the Milky Way galaxy.

**Activity** Draw a model of the Milky Way galaxy showing its spiral structure. Include the approximate location of the Sun.

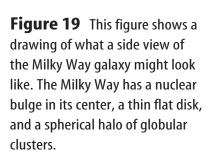
# The Milky Way

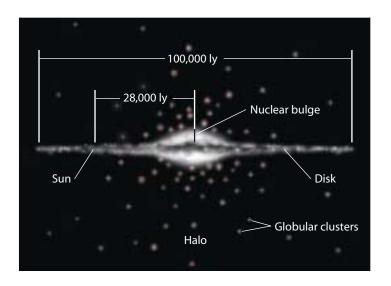
Recall that the Sun is one of possibly 200 to 400 billion stars in the Milky Way galaxy. A side view of the Milky Way galaxy is shown in **Figure 19.** Like most spiral galaxies, the Milky Way has three distinct parts. As shown in **Figure 19**, these three parts are the disk, the halo, and the nuclear bulge.

Reading Check What are the three parts of a spiral galaxy?

**The Galactic Disk** The disk of the Milky Way is about 100,000 light-years in diameter and contains the spiral arms. The spiral arms are regions where the concentration of dust and gas is higher, so that stars are being formed in the spiral arms. The Sun is in one of the spiral arms, about 28,000 light-years from the center of the galaxy. Because the Milky Way galaxy is rotating, the Sun moves around the center of the Milky Way at a speed of about 220 km/s. During its lifetime, the Sun has completed about 22 orbits of the galaxy. Although the Sun is about 5 billion years old, the Milky Way galaxy is much older. The oldest stars in the disk are about 9 to 10 billion years old.

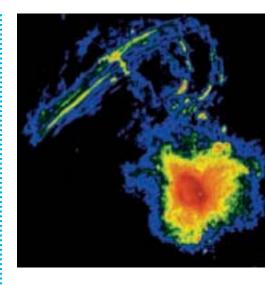
**The Halo** The halo is a roughly spherical region that surrounds the nuclear bulge and disk and might have a diameter of 200,000 light-years. The halo is made of globular clusters, which are groups of stars. Globular clusters typically contain about a million stars. Most of the oldest stars in the Milky Way found in the halo and are about 13 billion years old.





**The Nuclear Bulge** Stars are much closer together in the central region of spiral galaxies than in the disk. For example, in the vicinity of the Sun stars are typically 200 times farther apart than they are in the disk. This region of closely spaced stars forms a spherical bulge in the galaxy's center. Most of the stars in the central bulge are older stars. In some spiral galaxies the nuclear bulge is stretched so that it forms a bar across the center of the galaxy. These galaxies are called barred spiral galaxies. Observations by radio telescopes indicate that the Milky Way might be a barred spiral galaxy.

**The Galactic Center** The nuclear bulge of the Milky Way can't be seen from Earth because of clouds of dust and gas that prevent visible light from passing through. However, radio waves can pass through these gas and dust clouds. Data obtained by radio telescopes, such as the image shown in **Figure 20**, show that there is an object at the center of the galaxy that is emitting tremendous amounts of energy. This object, called Sgr A\* (saj ay star), is smaller than the solar system and has a mass of about 2.6 million times the mass of the Sun. Sgr A\* might be a black hole created by the merger of gas clouds and stars in the galaxy's center. Energy is emitted as hot gas spirals into the black hole.



**Figure 20** This image shows the intensity of radio waves emitted at the center of the Milky Way galaxy. A black hole might be at the center of the bright area on the lower right.

# section

# **Summary**

#### **Galaxies**

- A galaxy is a large group of stars, gas, and dust held together by gravity.
- The three main types of galaxies are elliptical, irregular, and spiral.

#### How do galaxies form?

- The attractive gravitational forces between galaxies can cause them to merge.
- Stars are so far apart compared to their size that when galaxies merge, stars usually don't collide, but just move past each other.

#### The Milky Way Galaxy

- The Milky Way galaxy contains about 200 to 400 billion stars and has a spiral shape.
- The Milky Way galaxy is about 100,000 lightyears across and the Sun lies about 28,000 light-years from its center.
- Spiral galaxies usually have a thin disk, a nuclear bulge, and a halo of globular clusters.

#### Self Check

- 1. Compare and contrast the Milky Way galaxy to other galaxies in the universe.
- 2. **Describe** the three main types of galaxies.
- 3. Draw the overall structure of the Milky Way galaxy and indicate where the Sun is located.
- **4. Describe** the Local Group of galaxies.

review

**5. Think Critically** How might the Sun be affected if the Andromeda galaxy and the Milky Way galaxy collide.

# **Applying Math**

- **6. Use Numbers** Assume there are 400 billion stars in the Milky Way galaxy, plus or minus 200 billion. Based on this estimate, what is the range of the number of stars that might exist in the Milky Way?
- **7. Use Percentages** A dwarf elliptical galaxy has fewer than 1 million stars and a small irregular galaxy contains 100 million stars. What percent of the number of stars found in a small irregular galaxy are found in a dwarf elliptical galaxy?



# Cosmology

# **Reading Guide**

# What You'll Learn

- Describe the most accepted theory about the origin of the universe.
- Define dark matter.
- Explain how dark energy may cause the universe to expand forever.

# Why It's Important

Conditions that existed when the universe began led to the formation of galaxies like the Milky Way.

## • Review Vocabulary

**universe:** the space that contains all known matter and energy

#### **New Vocabulary**

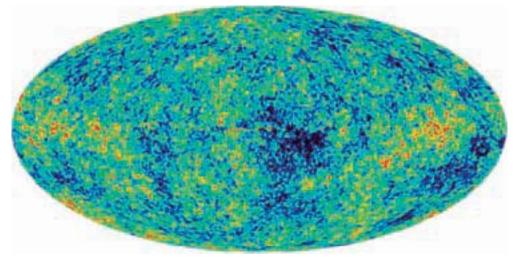
- cosmology
- big bang theory
- dark matter
- dark energy

# The Universe Is Expanding

The study of how the universe began, how it evolves, and what it is made of is called **cosmology**. An important discovery about the nature of the universe was made in 1929 by the astronomer Edwin Hubble. Hubble discovered that galaxies tend to be moving away from Earth. Hubble's observations also showed that the speed at which they moved depended on their distance from Earth. Galaxies that were farther from Earth moved faster.

Hubble's results could be explained if the universe were expanding. Imagine dots on a balloon. If the balloon expands, the dots get farther apart. If you select a single dot, all other dots are moving away with speeds that increase the farther they are from the selected dot.

Figure 21 This map shows small temperature variations in the cosmic background radiation. These temperature variations are due to temperature differences in different regions of the universe shortly after the big bang. The warmer regions are shown in red and the cooler regions in blue.



# **The Big Bang Theory**

Hubble's results and other data provide evidence that support the big bang theory of how the universe formed. According to the big bang theory, all matter and energy in the universe was compressed into a single point, which then began expanding outward. This expansion was not an explosion, but instead was an expansion of space itself. Initially the universe was extremely small and has been getting larger as it continues to expand.

The Cosmic Microwave Background Radiation In 1965 scientists detected microwaves that seemed to be coming from all directions in space. This radiation was predicted by the big bang theory and is called the cosmic background radiation.

Recently, detailed measurements of the cosmic background radiation have been made by an orbiting observatory called the Wilkinson Microwave Anisotropy Probe (WMAP). A map of these measurements is shown in Figure 21. The bright areas on the map show regions where the density of matter was high and galaxies first formed. The WMAP data and other data indicate that the big bang occurred about 13.7 billion years ago.

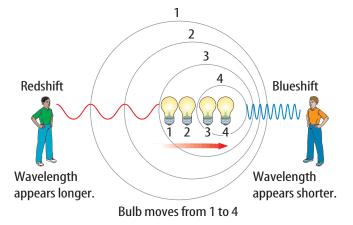
Reading Check When did the big bang occur?

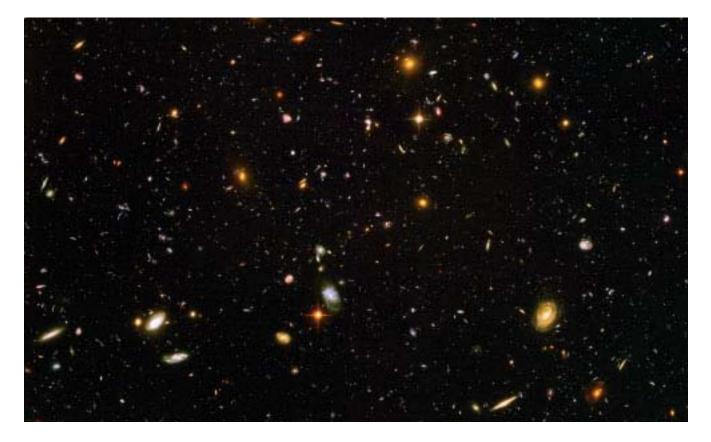
**Determining How Galaxies Move** The speed and direction of motion of galaxies can be determined by the Doppler effect. The Doppler effect occurs for a moving source of sound waves. As the source approaches, wavelengths become shorter and frequencies higher. As the source moves away, wavelengths become longer and frequencies lower. As shown in Figure 22, the Doppler effect also occurs for light waves. Hubble determined the universe was expanding by measuring the Doppler shift in the light emitted from galaxies. He found that the light from galaxies outside the Local Group is redshifted. This means that these galaxies are moving away from the Milky Way.

**Figure 22** The observer on the right experiences a blueshift as wavelengths of light emitted by an approaching object are shortened. The observer on the left experiences a redshift as wavelengths emitted by an object moving away are stretched.



Science as Literature Many famous scientists have written about science for the general public. Among them are physicists Albert Einstein and George Gamow. More recently, physicist Stephen Hawking wrote "A Brief History of Time," which describes current theories of how the universe began. Research the work of Steven Hawking and his contributions to cosmology and write a brief biography.





**Figure 23** This image was obtained by the *Hubble Space Telescope*. Almost all the objects in this image are galaxies. Some of these galaxies are the youngest and most distant galaxies known. The smallest and reddest galaxies might have formed almost 13 billion years ago.

**Hubble Redshift** Many observations have shown that the light from all distant galaxies is redshifted. However, the redshift of very distant galaxies is not due to the Doppler effect. Instead, it is caused by the stretching of space as the universe expands. The stretching of space causes the wavelengths of light waves to stretch and the light to be redshifted. This shift is known as the Hubble redshift. All the galaxies you can see in **Figure 23** are moving away from the Milky Way due to the expansion of the universe.

# What is the universe made of?

Stars and galaxies are made almost totally of hydrogen and helium gas, with small amounts of heavier elements. Hydrogen, helium, and the other elements form the stars, galaxies, and other objects that can be detected with various types of telescopes. However, over the past several decades, astronomers have found evidence for another type of matter that can't be detected with telescopes. This type of matter is called **dark matter** and can be detected only by its gravitational effects on ordinary matter. Observations show that there is about five to six times as much dark matter in the universe as ordinary matter.



How can the presence of dark matter be detected?

Dark Energy All matter in the universe exerts an attractive gravitational force on all other matter, including dark matter. These gravitational pulls might be strong enough to slow down the expansion of the universe. However, in the late 1990s, astronomers found that the expansion rate was speeding up. Astronomers hypothesized that an unknown repulsive force was causing the expansion to speed up. This repulsive force that

caused the expansion to speed up was due to the existence of a type of energy called **dark energy**. Astronomers estimate that of all the matter and energy in the universe, about 75 percent is dark energy, about 20 percent is dark matter, and only about 5 percent is ordinary matter we see.

Figure 24 These maps of sections of the universe show areas densely populated with galaxies and other areas almost empty. **Identify** What are the almostempty areas called?

The Structure of the Universe Astronomers have mapped the positions of thousands of galaxies in the universe. These maps, such as the one in Figure 24, show that the distribution of galaxies forms filaments. There are also enormous regions of space called voids where almost no galaxies exist.

#### section review

#### **Summary**

#### How did it begin?

- Cosmology is the study of how the universe began and evolves.
- The big bang theory is the most accepted theory about the beginning of the universe.
- The universe is estimated to be 13.7 billion years old.

#### **Expansion of the Universe**

- The Doppler effect indicates whether stars are coming toward Earth or moving away.
- The Hubble redshift is caused by the expansion of space and the entire universe.

#### What is the universe made of?

 The universe might contain dark matter and dark energy.

#### **Self Check**

- 1. **Define** cosmology.
- 2. **Describe** the big bang theory.
- 3. Explain how the expansion of space could cause a red shift in the light from distant galaxies.
- 4. **Describe** the Doppler effect.
- **5. Think Critically** How could the presence of some repulsing force cause the universe to expand forever?

## **Applying Math**

- **6. Use Percentages** The currently accepted age of the universe is 13.7 billion years plus or minus one percent. How much time does this one percent represent?
- 7. Use Percentages What percent of the universe's age is the first 400,000 years?



# **Model and Invent**

# Expansi n of the Universe

#### Goals

- Model the stretching of the wavelengths of light caused by the expansion of the universe.
- Measure the amount of wavelength lengthening produced in the model.
- Measure increases in distances between galaxy clusters caused by the expansion of the model.

#### **Possible Materials**

round balloon permanent marker (black or dark blue) medium-sized binder clip (3 cm)

# **Safety Precautions**



# Real-World Problem

You have read that the universe is expanding. In fact, recent calculations indicate that it is expanding more quickly now than it did in the past. Astronomers are able to measure this expansion because it stretches the wavelengths of light coming from distant objects. Can you make a model that demonstrates how this happens?

# Make a Model

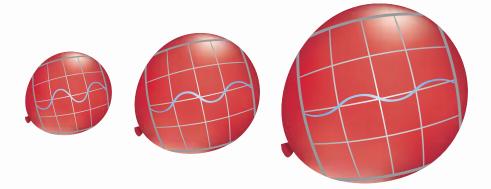
- 1. Work in teams of two or more. **Collect** all needed materials.
- **2.** Sketch an image on the balloon slightly inflated. **Model** the positions of galaxy clusters by placing three or four dots at four different locations and different distances apart on the surface of the balloon. Mark the locations R (for reference), A, B, and C.
- 3. Make a table for data.
- **4.** Check to see if the binder clip can hold air in the balloon long enough for you to make measurements and to draw on the balloon.
- **5.** Obtain your teacher's approval of your sketches and data table before proceeding.

# Test Your Model –

- 1. Slightly inflate your balloon so that it is not very big.
- 2. Use the binder clip to temporarily seal the balloon (or have your partner hold it closed). Do not tie it.
- **3. Measure** the distance from your reference galaxy cluster (R) to each of the other galaxy clusters and record these distances on your data table.

Data						
Location	First Distance Measurement	Second Distance Measurement	Change in Distance	First λ Measurement	Second \( \lambda \) Measurement	Change in $\lambda$
Α						
В	Do not write in this book.					
C						

# Using Scientific Methods



- **4.** Draw a wavy line from your reference galaxy cluster to each of the other galaxy clusters marked to represent the wavelength  $(\lambda)$  of light coming from each galaxy cluster. Measure and record the wavelength of each wavy line.
- **5.** Inflate your balloon farther (be careful not to inflate it too much). Replace the binder clip or tie the end shut.
- **6. Measure** and record the distances from your reference galaxy cluster to each of the other galaxy clusters.
- 7. Measure and record the wavelength of each wavy line on your inflated model.

# Analyze Your Data

- **1. Calculate** the change in distance and the change in wavelength for each galaxy cluster and record it on your data table.
- **2. Analyze** whether objects moved on your model or whether your entire model expanded.

# Conclude and Apply

- 1. Explain any changes in distance or wavelength noted.
- **2. Conclude** whether the objects moved apart because of their individual motions or because the model expanded.
- **3. Infer** how measurements on your model can be related to measurements of the universe.

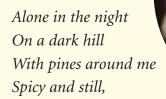


Enter the data from your model on a table that shows the data from all teams of students.

# Science Language

# **Stars**

Sara Teasdale



And a heaven full of stars Over my head, White and topaz And misty red;

Myriads with beating Hearts of fire That aeons Cannot vex or tire;

*Up the dome of heaven Like a great hill,* I watch them marching Stately and still,

And I know that I Am honored to be Witness Of so much majesty.

## **Understanding** Literature

**Imagery** Imagery refers to how a literary work invites the reader to see, hear, smell, touch, or taste something in his mind. Authors often use related images throughout a work, encouraging the reader to consider the subject using more than one sense. Of what specific senses does this poet make the reader aware?

#### Respond to the Reading

- 1. How does the author use personification to make the stars in the poem seem alive?
- 2. Tone refers to the overall mood of a literary work. Describe the tone of this poem.
- 3. Linking Science and Writing The poet refers to the color, age, energy source, and apparent movement of stars. Write a paragraph relating what you have learned about these properties to how they are mentioned in the poem.



On a clear, dark night, it is possible to

see as many as 1,500 stars with the unaided eye. However, this number is far lower because of light pollution. Light from houses, shopping areas, signs, and street lights floods the sky, making it difficult to see the stars. Inside major cities, fewer than 50 stars may be visible in the night sky.

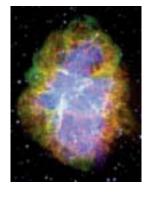
## **Reviewing Main Ideas**

## **Section 1 Observing the Universe**

- **1.** Constellations are patterns of stars that resemble things familiar to the observer.
- 2. Optical telescopes collect visible light and magnify viewed objects.
- **3.** A refracting telescope uses lenses to collect light and magnify the image, and a reflecting telescope uses a mirror to collect light and a lens to magnify the image.
- **4.** A radio telescope collects and amplifies radio waves.

#### **Section 2 Evolution of Stars**

**1.** Stars form from a large cloud of gas, ice, and dust, called a nebula like the one shown here. When the temperature inside the contracting nebula reaches 10 million K. fusion begins, and a star is born.



- 2. Stars are classified as main sequence stars, giants, supergiants, and white dwarfs on the H-R diagram.
- **3.** When a star reaches stellar equilibrium it is considered a main sequence star. When the hydrogen fuel is depleted, a star loses equilibrium and evolves into a giant or supergiant.
- **4.** After losing its outer layers, a giant becomes a white dwarf. A supergiant can evolve into a neutron star or a black hole.
- **5.** The Sun's energy is produced at its core by nuclear fusion.

## Section 3

#### **Galaxies and the Milky Way**

1. A galaxy is a large group of stars, gas, and dust held together by gravity. The Local Group of galaxies is a cluster that contains the Milky Way Galaxy.



- 2. The three main types of galaxies are elliptical, irregular, and spiral.
- **3.** Astronomers believe that galaxies form by absorbing or merging with smaller objects. They continue to evolve by colliding or merging with other galaxies.
- **4.** The Milky Way galaxy is about 100,000 light-years across and the Sun lies about 28,000 light-years from its center.

## Section 4 Cosmology

- **1.** The big bang theory is the most accepted theory of how the universe began.
- **2.** The universe is 13.7 billion years old and appears to be expanding faster now than in the past.
- **3.** The Hubble redshift is caused by the expansion of space, not the movement of galaxies.

FOLDABLES Use the Foldable that you made at the beginning of this chapter to help you review what you learned about cosmology.

## **Using Vocabulary**

big bang theory p. 837 constellation p. 818 cosmology p. 836 dark energy p. 839 dark matter p. 838 galaxy p. 831 giant p. 825 light-year p. 821 Local Group p. 832

main sequence p.823

Milky Way p. 831 photosphere p. 827 radio telescope p. 821 reflecting telescope p. 820 refracting telescope p. 819 solar mass p. 827 spectroscope p. 822 sunspots p. 828 white dwarf p. 825

Match the correct vocabulary word(s) with each definition given below.

- 1. patterns of stars
- **2.** an optical telescope that uses a mirror to collect light
- **3.** the distance light travels in one year
- **4.** plotted from the upper left to the lower right on the H-R diagram
- **5.** star in which the core contracts and outer layers expand and cool
- **6.** layer of the Sun from which light is emitted
- 7. dark, cooler areas on the Sun's photosphere
- **8.** large group of stars, gas, and dust held together by gravity
- **9.** spiral galaxy that contains the solar system
- **10.** study of the evolution of the universe

## **Checking Concepts**

Choose the word or phrase that best answers the question.

- **11.** Which telescope uses lenses to collect light and form an image?
  - **A)** adaptive
- c) reflecting
- **B)** radio
- **D)** refracting

- **12.** Which form of energy are optical telescopes used to study?
  - A) infrared radiation
  - **B)** radio waves
  - c) visible light
  - **D)** X rays
- 13. Which magnifies the image in a telescope?
  - A) eyepiece
- c) focus
- **B)** focal length
- **D)** objective
- **14.** Which is the most common type of star in the universe?
  - A) giant
- c) red dwarf
- **B)** neutron
- **D)** white dwarf
- **15.** Which forms from a star that is over 25 times the mass of the Sun?
  - A) black hole
- c) neutron star
- **B)** giant star
- **D)** white dwarf
- **16.** Which is a feature of the Sun that can reach 100 million K?
  - A) CME
- **c)** prominence
- **B)** flare
- **D)** sunspot

Use the illustration below to answer question 17.

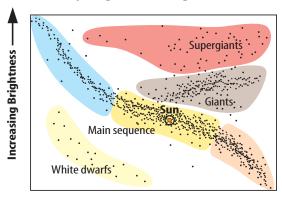


- 17. Which type of galaxy is the largest?
  - A) barred spiral
  - **B)** spiral
  - **c)** elliptical
  - **D)** irregular
- **18.** Which part of a spiral galaxy contains the oldest stars?
  - A) halo
- c) nuclear bulge
- **B)** disk
- **D)** photosphere

- **19.** Most of the matter in the universe has which form?
  - **A)** dark matter
  - **B)** dark energy
  - **C)** hydrogen gas
  - **D)** neutrons

#### **Interpreting Graphics**

- **20.** Make a table summarizing the brightness and temperatures of stars on this H-R diagram.
  - **Hertzsprung-Russell Diagram for Stars**



- **Decreasing Temperature**
- **21. Draw and label** scale models of the following stars: the Sun; Antares, 500 times larger than the Sun; and Sirius B 0.01 times the Sun's diameter.
- **22. Draw and label** a concept map showing the life history of a star like the Sun.
- 23. Draw and label the parts in a reflecting telescope.

## **Thinking Critically**

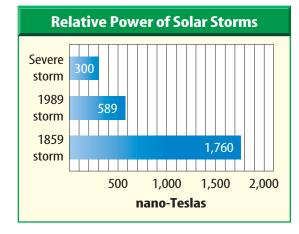
- **24.** Explain how energy created in the core of the Sun is eventually emitted from the photosphere.
- 25. Compare and contrast elliptical, irregular, and spiral galaxies.

- **26.** Discuss the benefits of using a radio telescope.
- **27. Explain** why high sunspot activity on the Sun can affect Earth's magnetic field.
- **28.** Explain how the Sun's position in the Milky Way affects how we perceive our galaxy.

#### **Applying Math**

**29.** Solve One-Step Equations Use the equation  $M_{\rm p} = f_{\rm o}/f_{\rm e}$ , to determine the magnifying power of a telescope in which the focal lengths of the objective and eyepiece are 1500 mm and 9 mm, respectively.

Use the illustration below to answer question 30.



- **30.** A solar storm that took place in 1859 is called "the perfect storm," because of its great power. The diagram shows the relative destructive power of some solar storms. Using this diagram, calculate approximately how much more destructive was the solar storm of 1859 than the one of 1989.
- **31. Calculate** how long ago the light we see today left a star that is 25 light-years away. Calculate the distance in km to that star.

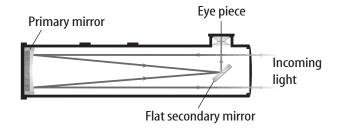
## Standardized Test Practice chapter

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

#### Multiple Choice

- **1.** What is used as an objective in a reflecting telescope?
  - A. antenna
  - **B.** camera
  - c. lens
  - **D.** mirror

#### Use the illustration below to answer question 2.



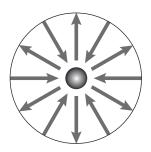
- **2.** Which type of telescope is shown?
  - **A.** optical
  - **B.** radio
  - **c.** ultraviolet
  - **D.** X-ray

## Test-Taking Tip

**Concentrate** Stay focused during the test and don't rush, even if you notice that other students are finishing the test early.

- **3.** Which group contains most stars on the H-R diagram?
  - A. giant
  - B. main sequence
  - **C.** supergiant
  - **D.** white dwarf
- **4.** Which stage of stellar evolution occurs when the outer layers escape, leaving behind the hot core?
  - A. black hole
  - B. giant
  - C. main sequence
  - **D.** white dwarf

#### Use the illustration below to answer guestion 5.



- **5.** What occurs inside a main sequence star?
  - **A.** Energy from fusion exceeds gravity.
  - **B.** Fusion shuts down.
  - **c.** Gravity exceeds energy from fusion.
  - **D.** It attains stellar equilibrium.

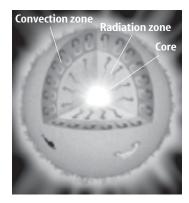
- **6.** Which may be responsible for the accelerating expansion of the universe?
  - **A.** dark energy
  - **B.** dark matter
  - **C.** regular energy
  - **D.** regular matter

#### **Gridded Response**

- **7.** If the focal length of a telescope objective is 2,400 mm and the focal length of the eyepiece is 20 mm, what is the magnifying power of the telescope?
- 8. Use this equation,  $A = \pi r^2$ . What is the area in square meters of one of the four 8.2-meter reflectors in the Very Large *Telescope?*

#### **Short Response**

Use the illustration below to answer question 9.

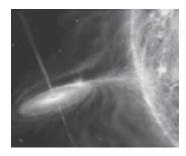


**9.** Describe the structure of the Sun's interior.

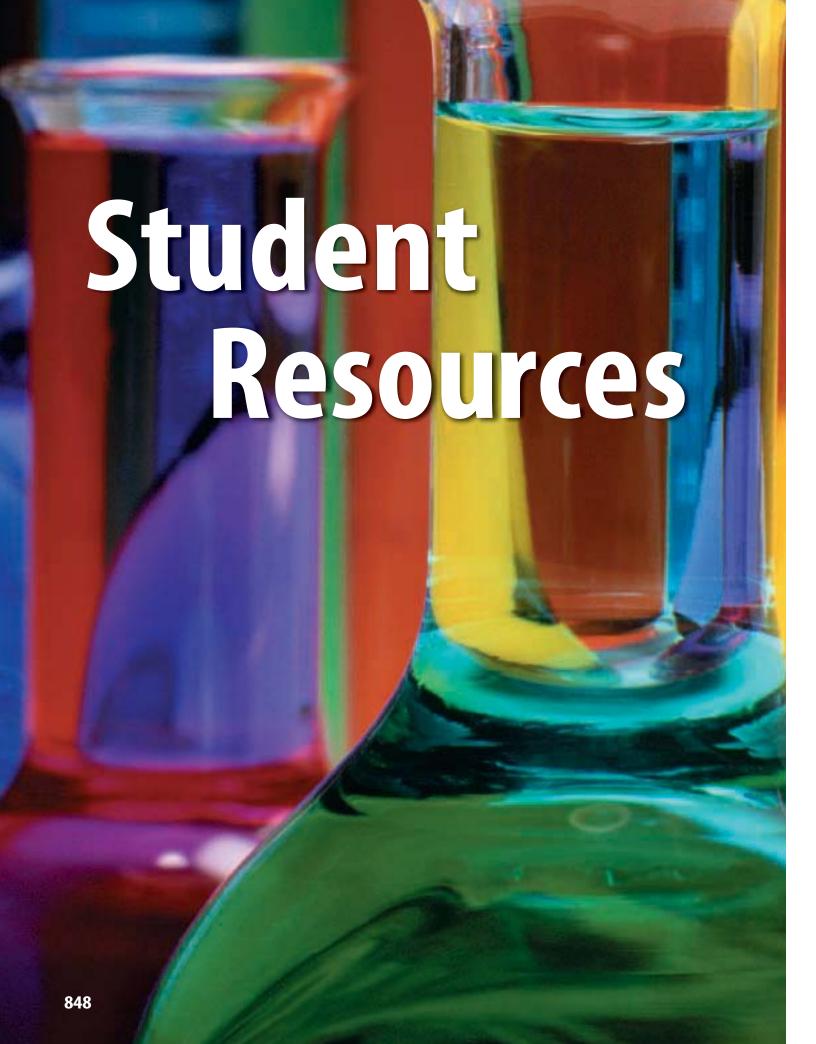
- **10.** What does a spectroscope do to starlight that enables astronomers to determine the star's composition?
- **11.** What does the H-R diagram show about the stars plotted on it?
- **12.** What are coronal mass ejections?
- **13.** What is the Local Group?
- **14.** How do astronomers think that galaxies like the Milky Way formed?
- **15.** What is cosmology?
- **16.** Why have astronomers proposed the existence of dark energy in the universe?



Use the photo below to help answer question 17.



- 17. PART A What are the evolutionary stages of a star like the Sun?
  - **PART B** What are the evolutionary stages of a star more than eight times the mass of the Sun?



# **Student Resources**

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# **Scientific Methods**

Scientists use an orderly approach called the scientific method to solve problems. This includes organizing and recording data so others can understand them. Scientists use many variations in this method when they solve problems.

#### **Identify a Question**

The first step in a scientific investigation or experiment is to identify a question to be answered or a problem to be solved. For example, you might ask which gasoline is the most efficient.

# Gather and Organize Information

After you have identified your question, begin gathering and organizing information. There are many ways to gather information, such as researching in a library, interviewing those knowledgeable about the subject, testing, and working in the laboratory and field. Fieldwork is investigations and observations done outside of a laboratory.

Researching Information Before moving in a new direction, it is important to gather the information that already is known about the subject. Start by asking yourself questions to determine exactly what you need to know. Then you will look for the information in various reference sources, like the student is doing in Figure 1. Some sources may include textbooks, encyclopedias, government documents, professional journals, science magazines, and the Internet. Always list the sources of your information.

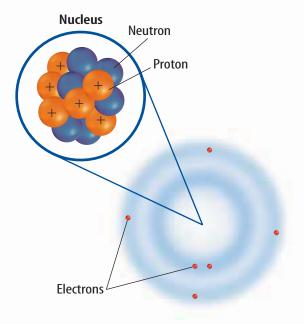


**Figure 1** The Internet can be a valuable research tool.

Evaluate Sources of Information Not all sources of information are reliable. You should evaluate all your sources of information, and use only those you know to be dependable. For example, if you are researching ways to make homes more energy efficient, a site written by the U.S. Department of Energy would be more reliable than a site written by a company that is trying to sell a new type of weatherproofing material. Also, remember that research always is changing. Consult the most current resources available to you. For example, a 1985 resource about saving energy would not reflect the most recent findings.

Sometimes scientists use data that they did not collect themselves, or conclusions drawn by other researchers. These data must be evaluated carefully. Ask questions about how the data were obtained, if the investigation was carried out properly, and if it has been duplicated exactly with the same results. Would you reach the same conclusion from the data? Only when you have confidence in the data can you believe it is true and feel comfortable using it.

Interpret Scientific Illustrations As you research a topic in science, you will see drawings, diagrams, and photographs to help you understand what you read. Some illustrations are included to help you understand an idea that you can't see easily by yourself, like the tiny particles in an atom in Figure 2. A drawing helps many people to remember details more easily and provides examples that clarify difficult concepts or give additional information about the topic you are studying. Most illustrations have labels or a caption to identify or to provide more information.

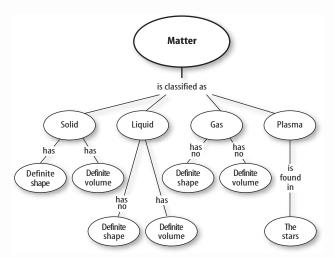


**Figure 2** This drawing shows an atom of carbon with its six protons, six neutrons, and six electrons.

**Concept Maps** One way to organize data is to draw a diagram that shows relationships among ideas (or concepts). A concept map can help make the meanings of ideas and terms more clear, and help you understand and remember what you are studying. Concept maps are useful for breaking large concepts down into smaller parts, making learning easier.

**Network Tree** A type of concept map that not only shows a relationship, but how the concepts are related is a network tree, shown in **Figure 3.** In a network tree, the words are written in the ovals, while the description of the type of relationship is written across the connecting lines.

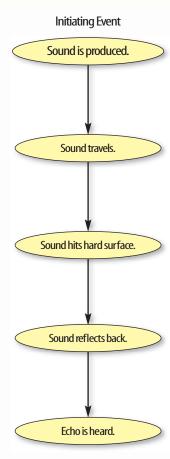
When constructing a network tree, write down the topic and all major topics on separate pieces of paper or notecards. Then arrange them in order from general to specific. Branch the related concepts from the major concept and describe the relationship on the connecting line. Continue to more specific concepts until finished.



**Figure 3** A network tree shows how concepts or objects are related.

**Events Chain** Another type of concept map is an events chain. Sometimes called a flow chart, it models the order or sequence of items. An events chain can be used to describe a sequence of events, the steps in a procedure, or the stages of a process.

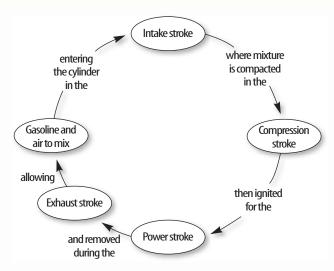
When making an events chain, first find the one event that starts the chain. This event is called the initiating event. Then, find the next event and continue until the outcome is reached, as shown in **Figure 4.** 



**Figure 4** Events-chain concept maps show the order of steps in a process or event. This concept map shows how a sound makes an echo.

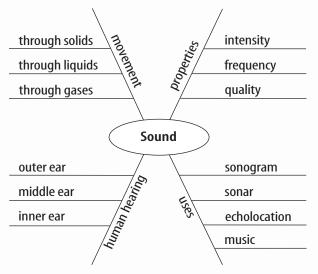
**Cycle Map** A specific type of events chain is a cycle map. It is used when the series of events do not produce a final outcome, but instead relate back to the beginning event, such as in **Figure 5.** Therefore, the cycle repeats itself.

To make a cycle map, first decide what event is the beginning event. This is also called the initiating event. Then list the next events in the order that they occur, with the last event relating back to the initiating event. Words can be written between the events that describe what happens from one event to the next. The number of events in a cycle map can vary, but usually contain three or more events.

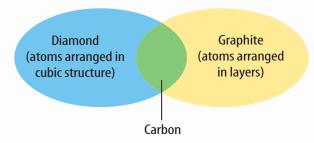


**Figure 5** A cycle map shows events that occur in a cycle.

**Spider Map** A type of concept map that you can use for brainstorming is the spider map. When you have a central idea, you might find that you have a jumble of ideas that relate to it but are not necessarily clearly related to each other. The spider map on sound in **Figure 6** shows that if you write these ideas outside the main concept, then you can begin to separate and group unrelated terms so they become more useful.



**Figure 6** A spider map allows you to list ideas that relate to a central topic but not necessarily to one another.



**Figure 7** This Venn diagram compares and contrasts two substances made from carbon.

**Venn Diagram** To illustrate how two subjects compare and contrast you can use a Venn diagram. You can see the characteristics that the subjects have in common and those that they do not, shown in **Figure 7.** 

To create a Venn diagram, draw two overlapping ovals that that are big enough to write in. List the characteristics unique to one subject in one oval, and the characteristics of the other subject in the other oval. The characteristics in common are listed in the overlapping section.

**Make and Use Tables** One way to organize information so it is easier to understand is to use a table. Tables can contain numbers, words, or both.

To make a table, list the items to be compared in the first column and the characteristics to be compared in the first row. The title should clearly indicate the content of the table, and the column or row heads should be clear. Notice that in **Table 1** the units are included.

Table 1 Recyclables Collected During Week			
Day of Week	Paper (kg)	Aluminum (kg)	Glass (kg)
Monday	5.0	4.0	12.0
Wednesday	4.0	1.0	10.0
Friday	2.5	2.0	10.0

Make a Model One way to help you better understand the parts of a structure, the way a process works, or to show things too large or small for viewing is to make a model. For example, an atomic model made of a plastic-ball nucleus and pipe-cleaner electron shells can help you visualize how the parts of an atom relate to each other. Other types of models can by devised on a computer or represented by equations.

## Form a Hypothesis

A possible explanation based on previous knowledge and observations is called a hypothesis. After researching gasoline types and recalling previous experiences in your family's car you form a hypothesis—our car runs more efficiently because we use premium gasoline. To be valid, a hypothesis has to be something you can test by using an investigation.

**Predict** When you apply a hypothesis to a specific situation, you predict something about that situation. A prediction makes a statement in advance, based on prior observation, experience, or scientific reasoning. People use predictions to make everyday decisions. Scientists test predictions by performing investigations. Based on previous observations and experiences, you might form a prediction that cars are more efficient with premium gasoline. The prediction can be tested in an investigation.

**Design an Experiment** A scientist needs to make many decisions before beginning an investigation. Some of these include: how to carry out the investigation, what steps to follow, how to record the data, and how the investigation will answer the question. It also is important to address any safety concerns.

## **Test the Hypothesis**

Now that you have formed your hypothesis, you need to test it. Using an investigation, you will make observations and collect data, or information. This data might either support or not support your hypothesis. Scientists collect and organize data as numbers and descriptions.

**Follow a Procedure** In order to know what materials to use, as well as how and in what order to use them, you must follow a procedure. **Figure 8** shows a procedure you might follow to test your hypothesis.

#### **Procedure**

- 1. Use regular gasoline for two weeks.
- 2. Record the number of kilometers between fill-ups and the amount of gasoline used.
- **3.** Switch to premium gasoline for two weeks.
- **4.** Record the number of kilometers between fill-ups and the amount of gasoline used.

**Figure 8** A procedure tells you what to do step by step.

Identify and Manipulate Variables and Controls In any experiment, it is important to keep everything the same except for the item you are testing. The one factor you change is called the independent variable. The change that results is the dependent variable. Make sure you have only one independent variable, to assure yourself of the cause of the changes you observe in the dependent variable. For example, in your gasoline experiment the type of fuel is the independent variable. The dependent variable is the efficiency.

Many experiments also have a control—an individual instance or experimental subject for which the independent variable is not changed. You can then compare the test results to the control results. To design a control you can have two cars of the same type. The control car uses regular gasoline for four weeks. After you are done with the test, you can compare the experimental results to the control results.

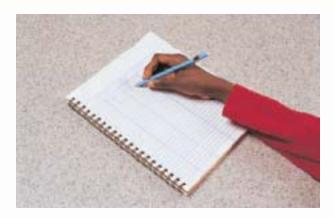
#### **Collect Data**

Whether you are carrying out an investigation or a short observational experiment, you will collect data, as shown in **Figure 9.** Scientists collect data as numbers and descriptions and organize it in specific ways.

**Observe** Scientists observe items and events, then record what they see. When they use only words to describe an observation, it is called qualitative data. Scientists' observations also can describe how much there is of something. These observations use numbers, as well as words, in the description and are called quantitative data. For example, if a sample of the element gold is described as being "shiny and very dense" the data are qualitative. Quantitative data on this sample of gold might include "a mass of 30 g and a density of 19.3 g/cm<sup>3</sup>."



**Figure 9** Collecting data is one way to gather information directly.



**Figure 10** Record data neatly and clearly so it is easy to understand.

When you make observations you should examine the entire object or situation first, and then look carefully for details. It is important to record observations accurately and completely. Always record your observations immediately as you make them, so you do not miss details or make a mistake when recording results from memory. Never put unidentified observations on scraps of paper. Instead they should be recorded in a notebook, like the one in **Figure 10.** Write your data neatly so you can easily read it later. At each point in the experiment, record your observations and label them. That way, you will not have to determine what the figures mean when you look at your notes later. Set up any tables that you will need to use ahead of time, so you can record any observations right away. Remember to avoid bias when collecting data by not including personal thoughts when you record observations. Record only what you observe.

**Estimate** Scientific work also involves estimating. To estimate is to make a judgment about the size or the number of something without measuring or counting. This is important when the number or size of an object or population is too large or too difficult to accurately count or measure.

**Sample** Scientists may use a sample or a portion of the total number as a type of estimation. To sample is to take a small, representative portion of the objects or organisms of a population for research. By making careful observations or manipulating variables within that portion of the group, information is discovered and conclusions are drawn that might apply to the whole population. A poorly chosen sample can be unrepresentative of the whole. If you were trying to determine the rainfall in an area, it would not be best to take a rainfall sample from under a tree.

**Measure** You use measurements every day. Scientists also take measurements when collecting data. When taking measurements, it is important to know how to use measuring tools properly. Accuracy also is important.

**Length** To measure length, the distance between two points, scientists use meters. Smaller measurements might be measured in centimeters or millimeters.

Length is measured using a metric ruler or meterstick. When using a metric ruler, line up the 0-cm mark with the end of the object being measured and read the number of the unit where the object ends. Look at the metric ruler shown in **Figure 11.** The centimeter lines are the long, numbered lines, and the shorter lines are millimeter lines. In this instance, the length would be 4.50 cm.



**Figure 11** This metric ruler has centimeter and millimeter divisions.

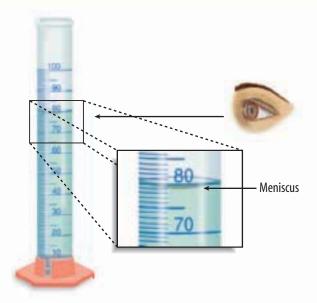
Mass The SI unit for mass is the kilogram (kg). Scientists can measure mass using units formed by adding metric prefixes to the unit gram (g), such as milligram (mg). To measure mass, you might use a triple-beam balance similar to the one shown in **Figure 12.** The balance has a pan on one side and a set of beams on the other side. Each beam has a rider that slides on the beam.

When using a triple-beam balance, place an object on the pan. Slide the largest rider along its beam until the pointer drops below zero. Then move it back one notch. Repeat the process for each rider proceeding from the larger to smaller until the pointer swings an equal distance above and below the zero point. Sum the masses on each beam to find the mass of the object. Move all riders back to zero when finished.

Instead of putting materials directly on the balance, scientists often take a tare of a container. A tare is the mass of a container into which objects or substances are placed for measuring their masses. To mass objects or substances, find the mass of a clean container. Remove the container from the pan, and place the object or substances in the container. Find the mass of the container with the materials in it. Subtract the mass of the empty container from the mass of the filled container to find the mass of the materials you are using.



**Figure 12** A triple-beam balance is used to determine the mass of an object.



**Figure 13** Graduated cylinders measure liquid volume.

**Liquid Volume** To measure liquids, the unit used is the liter (L). When a smaller unit is needed, scientists might use a milliliter (mL). Because a milliliter takes up the volume of a cube measuring 1 cm on each side it also can be called a cubic centimeter (cm<sup>3</sup> = cm  $\times$  cm  $\times$  cm).

You can use beakers and graduated cylinders to measure liquid volume. A graduated cylinder, shown in **Figure 13**, is marked from bottom to top in milliliters. In the lab, you might use a 10-mL graduated cylinder or a 100-mL graduated cylinder. When measuring liquids, notice that the liquid has a curved surface. Look at the surface at eye level, and measure the bottom of the curve. This is called the meniscus. The graduated cylinder in **Figure 13** contains 79.0 mL, or 79.0 cm<sup>3</sup>, of a liquid.

**Temperature** Scientists often measure temperature using the Celsius scale. Pure water has a freezing point of 0°C and boiling point of 100°C. The unit of measurement is degrees Celsius. Two other scales often used are the Fahrenheit and Kelvin scales.



**Figure 14** A thermometer measures the temperature of an object.

Scientists use a thermometer to measure temperature. Most thermometers in a laboratory are glass tubes with a bulb at the bottom end containing a liquid such as colored alcohol. The liquid rises or falls with a change in temperature. To read a glass thermometer like the thermometer in **Figure 14**, rotate it slowly until a red line appears. Read the temperature where the red line ends.

**Form Operational Definitions** An operational definition defines an object by how it functions, works, or behaves. For example, when you are playing hide and seek and a tree is home base, you have created an operational definition for a tree.

Objects can have more than one operational definition. For example, a ruler can be defined as a tool that measures the length of an object (how it is used). It can also be a tool with a series of marks used as a standard when measuring (how it works).

#### **Analyze the Data**

To determine the meaning of your observations and investigation results, you will need to look for patterns in the data. Then you must think critically to determine what the data mean. Scientists use several approaches when they analyze the data they have collected and recorded. Each approach is useful for identifying specific patterns.

Interpret Data The word interpret means "to explain the meaning of something." When analyzing data from an experiement, try to find out what the data show. Identify the control group and the test group to see whether or not changes in the independent variable have had an effect. Look for differences in the dependent variable between the control and test groups.

Classify Sorting objects or events into groups based on common features is called classifying. When classifying, first observe the objects or events to be classified. Then select one feature that is shared by some members in the group, but not by all. Place those members that share that feature in a subgroup. You can classify members into smaller and smaller subgroups based on characteristics. Remember that when you classify, you are grouping objects or events for a purpose. Keep your purpose in mind as you select the features to form groups and subgroups.

Compare and Contrast Observations can be analyzed by noting the similarities and differences between two more objects or events that you observe. When you look at objects or events to see how they are similar, you are comparing them. Contrasting is looking for differences in objects or events.

**Recognize Cause and Effect** A cause is a reason for an action or condition. The effect is that action or condition. When two events happen together, it is not necessarily true that one event caused the other. Scientists must design a controlled investigation to recognize the exact cause and effect.

#### **Draw Conclusions**

When scientists have analyzed the data they collected, they proceed to draw conclusions about the data. These conclusions are sometimes stated in words similar to the hypothesis that you formed earlier. They may confirm a hypothesis, or lead you to a new hypothesis.

**Infer** Scientists often make inferences based on their observations. An inference is an attempt to explain observations or to indicate a cause. An inference is not a fact, but a logical conclusion that needs further investigation. For example, you may infer that a fire has caused smoke. Until you investigate, however, you do not know for sure.

Apply When you draw a conclusion, you must apply those conclusions to determine whether the data support the hypothesis. If your data do not support your hypothesis, it does not mean that the hypothesis is wrong. It means only that the result of the investigation did not support the hypothesis. Maybe the experiment needs to be redesigned, or some of the initial observations on which the hypothesis was based were incomplete or biased. Perhaps more observation or research is needed to refine your hypothesis. A successful investigation does not always come out the way you originally predicted.

**Avoid Bias** Sometimes a scientific investigation involves making judgments. When you make a judgment, you form an opinion. It is important to be honest and not to allow any expectations of results to bias your judgments. This is important throughout the entire investigation, from researching to collecting data to drawing conclusions.

#### **Communicate**

The communication of ideas is an important part of the work of scientists. A discovery that is not reported will not advance the scientific community's understanding or knowledge. Communication among scientists also is important as a way of improving their investigations.

Scientists communicate in many ways, from writing articles in journals and magazines that explain their investigations and experiments, to announcing important discoveries on television and radio. Scientists also share ideas with colleagues on the Internet or present them as lectures, like the student is doing in **Figure 15**.



**Figure 15** A student communicates to his peers about his investigation.

SAFETY SYMBOLS	HAZARD	EXAMPLES	PRECAUTION	REMEDY
DISPOSAL	Special disposal procedures need to be followed.	certain chemicals, living organisms	Do not dispose of these materials in the sink or trash can.	Dispose of wastes as directed by your teacher.
BIOLOGICAL	Organisms or other biological materials that might be harmful to humans	bacteria, fungi, blood, unpreserved tissues, plant materials	Avoid skin contact with these materials. Wear mask or gloves.	Notify your teacher if you suspect contact with material. Wash hands thoroughly.
EXTREME TEMPERATURE	Objects that can burn skin by being too cold or too hot	boiling liquids, hot plates, dry ice, liquid nitrogen	Use proper protection when handling.	Go to your teacher for first aid.
SHARP OBJECT	Use of tools or glass- ware that can easily puncture or slice skin	razor blades, pins, scalpels, pointed tools, dissecting probes, bro- ken glass	Practice common- sense behavior and follow guidelines for use of the tool.	Go to your teacher for first aid.
FUME C	Possible danger to respiratory tract from fumes	ammonia, acetone, nail polish remover, heated sulfur, moth balls	Make sure there is good ventilation. Never smell fumes directly. Wear a mask.	Leave foul area and notify your teacher immediately.
ELECTRICAL	Possible danger from electrical shock or burn	improper grounding, liquid spills, short circuits, exposed wires	Double-check setup with teacher. Check condition of wires and apparatus.	Do not attempt to fix electrical problems. Notify your teacher immediately.
IRRITANT	Substances that can irritate the skin or mucous membranes of the respiratory tract	pollen, moth balls, steel wool, fiberglass, potassium perman- ganate	Wear dust mask and gloves. Practice extra care when handling these materials.	Go to your teacher for first aid.
CHEMICAL	Chemicals can react with and destroy tissue and other materials	bleaches such as hydrogen peroxide; acids such as sulfuric acid, hydrochloric acid; bases such as ammo- nia, sodium hydroxide	Wear goggles, gloves, and an apron.	Immediately flush the affected area with water and notify your teacher.
тохіс	Substance may be poisonous if touched, inhaled, or swallowed.	mercury, many metal compounds, iodine, poinsettia plant parts	Follow your teacher's instructions.	Always wash hands thoroughly after use. Go to your teacher for first aid.
FLAMMABLE (8)	Flammable chemicals may be ignited by open flame, spark, or exposed heat.	alcohol, kerosene, potassium perman- ganate	Avoid open flames and heat when using flammable chemicals.	Notify your teacher immediately. Use fire safety equipment if applicable.
OPEN FLAME	Open flame in use, may cause fire.	hair, clothing, paper, synthetic materials	Tie back hair and loose clothing. Follow teacher's instruction on lighting and extinguishing flames.	Notify your teacher immediately. Use fire safety equipment if applicable.



#### **Eye Safety**

Proper eye protection should be worn at all times by anyone performing or observing science activities.



#### Clothing Protection

This symbol appears when substances could stain or burn clothing.



#### **Animal Safety**

This symbol appears when safety of animals and students must be ensured.



#### Handwashing

After the lab, wash hands with soap and water before removing goggles.

# **Introduction to Science Safety**

Confucius, an ancient and well-known Chinese philosopher, is credited with a statement that could serve as a legacy of all types of human wisdom. It seems especially appropriate for the active learning you will experience in this science program.

"I hear and I forget, I see and I remember, I do and I understand."

This is the basis for the safety routine that will be used in all the labs in this book. It is assumed that you will use all of your senses as you "experience" the labs. However, with such experience comes the potential for injury. The purpose of this section of the book is to help keep you safe by involving you in the safety process.

## How will your teacher help?

It will be your teacher's responsibility to decide which science labs are safe and appropriate for you. Your teacher will identify the hazards involved in each activity and likely will ask for your assistance for ways to reduce the dangers as much as possible. He or she will involve you regularly in safety discussions about your understanding of the actual and potential dangers and the safety measures needed to keep everyone safe. Ideally, this will become a habit with each lab in which you take part.

Your teacher also will explain the safety features of your room as well as the most important safety equipment and routines for addressing safety issues. He or she will also require that you complete a *Student Lab-Safety Form* for each lab to make certain you are prepared to perform the lab safely.



Your teacher will review your comments, make corrections, and sign or initial this form **BEFORE** you will be permitted to begin the lab.

The ultimate purpose of the safety discussions and the *Student Lab-Safety Form* will be to *help you take some responsibility for your own safety* and to help you to develop good habits when you prepare and perform science experiments and labs.

## How can you help?

Since your teacher cannot anticipate every safety hazard that might occur and he or she cannot be everywhere in the room at the same time, you need to take some responsibility for your own safety. The following general information should apply to nearly every science lab in which you will be involved as part of this class.

Adapted from Gerlovich, et al. (2004). The Total Science Safety System D. JaKel, Inc. http://www.netins.net/showcase/jakel. Used with Permission



#### You must:

- Review any Safety Symbols in the labs and be certain that you know what they mean.
- Follow all teacher instructions for safety and make certain that you understand all the hazards related to the labs you are about to do.
- Be able to explain the purpose of the lab.
- Be able to explain, or demonstrate, all reasonable emergency procedures, such as:
  - how to evacuate the room during emergencies;
  - how to react to any chemical emergencies;
  - how to deal with fire emergencies;
  - how to perform a scientific investigation safely;
  - how to anticipate some safety concerns and be prepared to address them;
  - how to use equipment properly and safely.

- Be able to locate and use all safety equipment as directed by your teacher, such as:
  - fire extinguishers;
  - fire blankets;
  - eye protective equipment (goggles, safety glasses, face shield);
  - eyewash;
  - drench shower.
- Complete the Student Lab-Safety Form before starting any science lab.
- Ask questions about any safety concerns that you might have BEFORE starting any lab of science investigation.

Remember! Your teacher will review your comments, make corrections, and sign or initial the *Student Lab-Safety Form* **BEFORE** you will be permitted to begin the lab. A copy of this form appears below.

Date:	
Lab Title:	Teacher Approval Initials
	Date of Approval
In order to show your teacher that you understand t following questions must be answered after the teach You must have your teacher initial this form before	her explains the information to you.
How would you describe what you will be doing of	during this lab?
What are the safety concerns in this lab (explained)	l by your teacher)?
3. What additional safety concerns or questions do y	ou have?
3. What additional safety concerns or questions do y	rou have?
3. What additional safety concerns or questions do y	rou have?
3. What additional safety concerns or questions do y	rou have?

Adapted from Gerlovich, et al. (2004). The Total Science Safety System D. JaKel, Inc. http://www.netins.net/showcase/jakel. Used with Permission

# **Math Review**

#### **Use Fractions**

A fraction compares a part to a whole. In the fraction  $\frac{2}{3}$ , the 2 represents the part and is the numerator. The 3 represents the whole and is the denominator.

**Reduce Fractions** To reduce a fraction, you must find the largest factor that is common to both the numerator and the denominator, the greatest common factor (GCF). Divide both numbers by the GCF. The fraction has then been reduced, or it is in its simplest form.

**Example** Twelve of the 20 chemicals in the science lab are in powder form. What fraction of the chemicals used in the lab are in powder form?

Step 1 Write the fraction.

$$\frac{\text{part}}{\text{whole}} = \frac{12}{20}$$

- Step 2 To find the GCF of the numerator and denominator, list all of the factors of each number.

  Factors of 12: 1, 2, 3, 4, 6, 12 (the numbers that divide evenly into 12)

  Factors of 20: 1, 2, 4, 5, 10, 20 (the numbers that divide evenly into 20)
- **Step 3** List the common factors. 1, 2, 4
- **Step 4** Choose the greatest factor in the list. The GCF of 12 and 20 is 4.
- **Step 5** Divide the numerator and denominator by the GCF.

$$\frac{12 \div 4}{20 \div 4} = \frac{3}{5}$$

In the lab,  $\frac{3}{5}$  of the chemicals are in powder form.

**Practice Problem** At an amusement park, 66 of 90 rides have a height restriction. What fraction of the rides, in its simplest form, has a height restriction?

**Add and Subtract Fractions** To add or subtract fractions with the same denominator, add or subtract the numerators and write the sum or difference over the denominator. After finding the sum or difference, find the simplest form for your fraction.

**Example 1** In the forest outside your house,  $\frac{1}{8}$  of the animals are rabbits,  $\frac{3}{8}$  are squirrels, and the remainder are birds and insects. How many are mammals?

**Step 1** Add the numerators.

$$\frac{1}{8} + \frac{3}{8} = \frac{(1+3)}{8} = \frac{4}{8}$$

**Step 2** Find the GCF.

$$\frac{4}{8}$$
 (GCF, 4)

**Step 3** Divide the numerator and denominator by the GCF.

$$\frac{4 \div 4}{8 \div 4} = \frac{1}{2}$$

 $\frac{1}{2}$  of the animals are mammals.

**Example 2** If  $\frac{7}{16}$  of the Earth is covered by

freshwater, and  $\frac{1}{16}$  of that is in glaciers, how much freshwater is not frozen?

**Step 1** Subtract the numerators.

$$\frac{7}{16} - \frac{1}{16} = \frac{(7-1)}{16} = \frac{6}{16}$$

**Step 2** Find the GCF.

$$\frac{6}{16}$$
 (GCF, 2)

**Step 3** Divide the numerator and denominator by

$$\frac{6 \div 2}{16 \div 2} = \frac{3}{8}$$

 $\frac{3}{8}$  of the freshwater is not frozen.

**Practice Problem** A bicycle rider is riding at a rate of 15 km/h for  $\frac{4}{9}$  of his ride, 10 km/h for  $\frac{2}{9}$  of his ride, and 8 km/h for the remainder of the ride. How much of his ride is he riding at a rate greater than 8 km/h?

**Unlike Denominators** To add or subtract fractions with unlike denominators, first find the least common denominator (LCD). This is the smallest number that is a common multiple of both denominators. Rename each fraction with the LCD, and then add or subtract. Find the simplest form if necessary.

**Example 1** A chemist makes a paste that is  $\frac{1}{2}$  table salt (NaCl),  $\frac{1}{3}$  sugar (C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>), and the remainder is water (H<sub>2</sub>0). How much of the paste is a solid?

**Step 1** Find the LCD of the fractions.

$$\frac{1}{2} + \frac{1}{3}$$
 (LCD, 6)

**Step 2** Rename each numerator and each denominator with the LCD.

**Step 3** Add the numerators.

$$\frac{3}{6} + \frac{2}{6} = \frac{(3+2)}{6} = \frac{5}{6}$$

 $\frac{5}{6}$  of the paste is a solid.

**Example 2** The average precipitation in Grand Junction, CO, is  $\frac{7}{10}$  inch in November, and  $\frac{3}{5}$  inch in December. What is the total average precipitation?

**Step 1** Find the LCD of the fractions.

$$\frac{7}{10} + \frac{3}{5}$$
 (LCD, 10)

**Step 2** Rename each numerator and each denominator with the LCD.

**Step 3** Add the numerators.

$$\frac{7}{10} + \frac{6}{10} = \frac{(7+6)}{10} = \frac{13}{10}$$

 $\frac{13}{10}$  inches total precipitation, or  $1\frac{3}{10}$  inches.

**Practice Problem** On an electric bill, about  $\frac{1}{8}$  of the energy is from solar energy and about  $\frac{1}{10}$  is from wind power. How much of the total bill is from solar energy and wind power combined?

**Example 3** In your body,  $\frac{1}{10}$  of your muscle contractions are involuntary (cardiac and smooth muscle tissue). Smooth muscle makes  $\frac{3}{15}$  of your muscle contractions. How many of your muscle contractions are made by cardiac muscle?

**Step 1** Find the LCD of the fractions.

$$\frac{7}{10} - \frac{3}{15}$$
 (LCD, 30)

Step 2 Rename each numerator and each denominator with the LCD.

$$7 \times 3 = 21, 10 \times 3 = 30$$
  
 $3 \times 2 = 6, 15 \times 2 = 30$ 

**Step 3** Subtract the numerators. 
$$\frac{21}{30} - \frac{6}{30} = \frac{(21-6)}{30} = \frac{15}{30}$$

Step 4 Find the GCF.

$$\frac{15}{30}$$
 (GCF, 15)

 $\frac{1}{2}$  of all muscle contractions are cardiac muscle.

**Example 4** Tony wants to make cookies that call for  $\frac{3}{4}$  of a cup of flour, but he only has  $\frac{1}{3}$  of a cup. How much more flour does he need?

**Step 1** Find the LCD of the fractions.

$$\frac{3}{4} - \frac{1}{3}$$
 (LCD, 12)

Step 2 Rename each numerator and each denominator with the LCD.

$$\frac{3\times3}{4\times3} = \frac{9}{12}$$
$$\frac{1\times4}{3\times4} = \frac{4}{12}$$

**Step 3** Subtract the numerators.

$$\frac{9}{12} - \frac{4}{12} = \frac{(9-4)}{12} = \frac{5}{12}$$

 $\frac{5}{12}$  of a cup of flour

**Practice Problem** Using the information provided to you in Example 3 above, determine how many muscle contractions are voluntary (skeletal muscle).

**Multiply Fractions** To multiply with fractions, multiply the numerators and multiply the denominators. Find the simplest form if necessary.

**Example** Multiply  $\frac{3}{5}$  by  $\frac{1}{3}$ .

- **Step 1** Multiply the numerators and denominators.  $\frac{3}{5} \times \frac{1}{3} = \frac{(3 \times 1)}{(5 \times 3)} = \frac{3}{15}$
- **Step 2** Find the GCF.  $\frac{3}{15}$  (GCF, 3)
- **Step 3** Divide the numerator and denominator by the GCF.
  - $\frac{3 \div 3}{15 \div 3} = \frac{1}{5}$
- $\frac{3}{5}$  multiplied by  $\frac{1}{3}$  is  $\frac{1}{5}$ .

**Practice Problem** Multiply  $\frac{3}{14}$  by  $\frac{5}{16}$ .

**Find a Reciprocal** Two numbers whose product is 1 are called multiplicative inverses, or reciprocals.

**Example** Find the reciprocal of  $\frac{3}{8}$ .

**Step 1** Inverse the fraction by putting the denominator on top and the numerator on the bottom.

<u>8</u>

The reciprocal of  $\frac{3}{8}$  is  $\frac{8}{3}$ .

**Practice Problem** Find the reciprocal of  $\frac{4}{9}$ .

**Divide Fractions** To divide one fraction by another fraction, multiply the dividend by the reciprocal of the divisor. Find the simplest form if necessary.

**Example 1** Divide  $\frac{1}{9}$  by  $\frac{1}{3}$ .

- **Step 1** Find the reciprocal of the divisor. The reciprocal of  $\frac{1}{3}$  is  $\frac{3}{1}$ .
- **Step 2** Multiply the dividend by the reciprocal of the divisor.

$$\frac{\frac{1}{9}}{\frac{1}{3}} = \frac{1}{9} \times \frac{3}{1} = \frac{(1 \times 3)}{(9 \times 1)} = \frac{3}{9}$$

- **Step 3** Find the GCF.  $\frac{3}{9}$  (GCF, 3)
- **Step 4** Divide the numerator and denominator by the GCF.

$$\frac{3 \div 3}{9 \div 3} = \frac{1}{3}$$

 $\frac{1}{9}$  divided by  $\frac{1}{3}$  is  $\frac{1}{3}$ .

**Example 2** Divide  $\frac{3}{5}$  by  $\frac{1}{4}$ .

- **Step 1** Find the reciprocal of the divisor. The reciprocal of  $\frac{1}{4}$  is  $\frac{4}{1}$ .
- **Step 2** Multiply the dividend by the reciprocal of the divisor.

$$\frac{\frac{3}{5}}{\frac{1}{4}} = \frac{3}{5} \times \frac{4}{1} = \frac{(3 \times 4)}{(5 \times 1)} = \frac{12}{5}$$

 $\frac{3}{5}$  divided by  $\frac{1}{4}$  is  $\frac{12}{5}$  or  $2\frac{2}{5}$ .

**Practice Problem** Divide  $\frac{3}{11}$  by  $\frac{7}{10}$ .

#### **Use Ratios**

When you compare two numbers by division, you are using a ratio. Ratios can be written 3 to 5, 3:5, or  $\frac{3}{5}$ . Ratios, like fractions, also can be written in simplest form.

Ratios can represent one type of probability, called odds. This is a ratio that compares the number of ways a certain outcome occurs to the number of possible outcomes. For example, if you flip a coin 100 times, what are the odds that it will come up heads? There are two possible outcomes, heads or tails, so the odds of coming up heads are 50:100. Another way to say this is that 50 out of 100 times the coin will come up heads. In its simplest form, the ratio is 1:2.

**Example 1** A chemical solution contains 40 g of salt and 64 g of baking soda. What is the ratio of salt to baking soda as a fraction in simplest form?

**Step 1** Write the ratio as a fraction.

$$\frac{\text{salt}}{\text{baking soda}} = \frac{40}{64}$$

**Step 2** Express the fraction in simplest form.

The GCF of 40 and 64 is 8.

$$\frac{40}{64} = \frac{40 \div 8}{64 \div 8} = \frac{5}{8}$$

The ratio of salt to baking soda in the sample is 5:8.

**Example 2** Sean rolls a 6-sided die 6 times. What are the odds that the side with a 3 will show?

**Step 1** Write the ratio as a fraction.

$$\frac{\text{number of sides with a 3}}{\text{number of possible sides}} = \frac{1}{6}$$

**Step 2** Multiply by the number of attempts.

$$\frac{1}{6} \times 6$$
 attempts  $= \frac{6}{6}$  attempts  $= 1$  attempt

1 attempt out of 6 will show a 3.

**Practice Problem** Two metal rods measure 100 cm and 144 cm in length. What is the ratio of their lengths in simplest form?

#### **Use Decimals**

A fraction with a denominator that is a power of ten can be written as a decimal. For example, 0.27 means  $\frac{27}{100}$ . The decimal point separates the ones place from the tenths place.

Any fraction can be written as a decimal using division. For example, the fraction  $\frac{5}{8}$ can be written as a decimal by dividing 5 by 8. Written as a decimal, it is 0.625.

**Add or Subtract Decimals** When adding and subtracting decimals, line up the decimal points before carrying out the operation.

**Example 1** Find the sum of 47.68 and 7.80.

**Step 1** Line up the decimal places when you write the numbers.

**Step 2** Add the decimals.

$$\begin{array}{r}
 11 \\
 47.68 \\
 + 7.80 \\
 \hline
 55.48
 \end{array}$$

The sum of 47.68 and 7.80 is 55.48.

**Example 2** Find the difference of 42.17 and 15.85.

**Step 1** Line up the decimal places when you write the number.

**Step 2** Subtract the decimals.

The difference of 42.17 and 15.85 is 26.32.

**Practice Problem** Find the sum of 1.245 and 3.842.

**Multiply Decimals** To multiply decimals, multiply the numbers like you multiply numbers without decimals. Count the decimal places in each factor. The product will have the same number of decimal places as the sum of the decimal places in the factors.

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**Example** Multiply 2.4 by 5.9.

- **Step 1** Multiply the factors like two whole numbers.  $24 \times 59 = 1416$
- **Step 2** Find the sum of the number of decimal places in the factors. Each factor has one decimal place, for a sum of two decimal places.
- **Step 3** The product will have two decimal places. 14.16

The product of 2.4 and 5.9 is 14.16.

**Practice Problem** Multiply 4.6 by 2.2.

**Divide Decimals** When dividing decimals, change the divisor to a whole number. To do this, multiply both the divisor and the dividend by the same power of ten. Then place the decimal point in the quotient directly above the decimal point in the dividend. Then divide as you do with whole numbers.

**Example** Divide 8.84 by 3.4.

**Step 1** Multiply both factors by 10.  $3.4 \times 10 = 34, 8.84 \times 10 = 88.4$ 

**Step 2** Divide 88.4 by 34.

$$\begin{array}{r}
 2.6 \\
 34)88.4 \\
 -68 \\
 204 \\
 -204 \\
 0
\end{array}$$

8.84 divided by 3.4 is 2.6.

**Practice Problem** Divide 75.6 by 3.6.

#### **Use Proportions**

An equation that shows that two ratios are equivalent is a proportion. The ratios  $\frac{2}{4}$  and  $\frac{5}{10}$  are equivalent, so they can be written as  $\frac{2}{4} = \frac{5}{10}$ . This equation is a proportion.

When two ratios form a proportion, the cross products are equal. To find the cross products in the proportion  $\frac{2}{4} = \frac{5}{10}$ , multiply the 2 and the 10, and the 4 and the 5. Therefore  $2 \times 10 = 4 \times 5$ , or 20 = 20.

Because you know that both ratios are equal, you can use cross products to find a missing term in a proportion. This is known as solving the proportion.

**Example** The heights of a tree and a pole are proportional to the lengths of their shadows. The tree casts a shadow of 24 m when a 6-m pole casts a shadow of 4 m. What is the height of the tree?

- Step 1 Write a proportion.  $\frac{\text{height of tree}}{\text{height of pole}} = \frac{\text{length of tree's shadow}}{\text{length of pole's shadow}}$
- **Step 2** Substitute the known values into the proportion. Let *h* represent the unknown value, the height of the tree.

$$\frac{h}{6} = \frac{24}{4}$$

**Step 3** Find the cross products.  $h \times 4 = 6 \times 24$ 

**Step 4** Simplify the equation. 4h = 144

**Step 5** Divide each side by 4. 4*h* 144

$$\frac{4h}{4} = \frac{144}{4}$$
 $h = 36$ 

The height of the tree is 36 m.

**Practice Problem** The ratios of the weights of two objects on the Moon and on Earth are in proportion. A rock weighing 3 N on the Moon weighs 18 N on Earth. How much would a rock that weighs 5 N on the Moon weigh on Earth?

#### **Use Percentages**

The word percent means "out of one hundred." It is a ratio that compares a number to 100. Suppose you read that 77 percent of the Earth's surface is covered by water. That is the same as reading that the fraction of the Earth's surface covered by water is  $\frac{77}{100}$ . To express a fraction as a percent, first find the equivalent decimal for the fraction. Then, multiply the decimal by 100 and add the percent symbol.

**Example** Express  $\frac{13}{20}$  as a percent.

**Step 1** Find the equivalent decimal for the fraction.

**Step 2** Rewrite the fraction  $\frac{13}{20}$  as 0.65.

**Step 3** Multiply 0.65 by 100 and add the % symbol.  $0.65 \times 100 = 65 = 65\%$ 

So, 
$$\frac{13}{20} = 65\%$$
.

This also can be solved as a proportion.

**Example** Express  $\frac{13}{20}$  as a percent.

**Step 1** Write a proportion.

$$\frac{13}{20} = \frac{x}{100}$$

**Step 2** Find the cross products.

$$1300 = 20x$$

**Step 3** Divide each side by 20.

$$\frac{1300}{20} = \frac{20x}{20}$$
$$65\% = x$$

**Practice Problem** In one year, 73 of 365 days were rainy in one city. What percent of the days in that city were rainy?

#### **Solve One-Step Equations**

A statement that two expressions are equal is an equation. For example, A = B is an equation that states that A is equal to B.

An equation is solved when a variable is replaced with a value that makes both sides of the equation equal. To make both sides equal the inverse operation is used. Addition and subtraction are inverses, and multiplication and division are inverses.

**Example 1** Solve the equation x - 10 = 35.

**Step 1** Find the solution by adding 10 to each side of the equation.

$$x - 10 = 35$$
  
 $x - 10 + 10 = 35 + 10$   
 $x = 45$ 

**Step 2** Check the solution.

$$x - 10 = 35$$
  
 $45 - 10 = 35$   
 $35 = 35$ 

Both sides of the equation are equal, so x = 45.

**Example 2** In the formula a = bc, find the value of c if a = 20 and b = 2.

**Step 1** Rearrange the formula so the unknown value is by itself on one side of the equation by dividing both sides by 
$$a = bc$$
  $a = bc$   $b$   $a = bc$   $b$ 

**Step 2** Replace the variables 
$$a$$
  $\frac{a}{b} = c$  and  $b$  with the values that are given.  $\frac{20}{2} = c$   $10 = c$ 

**Step 3** Check the solution. 
$$a = bc$$
  $20 = 2 \times 10$   $20 = 20$ 

Both sides of the equation are equal, so c = 10 is the solution when a = 20 and b = 2.

**Practice Problem** In the formula h = qd, find the value of *d* if q = 12.3 and h = 17.4.

#### **Use Statistics**

The branch of mathematics that deals with collecting, analyzing, and presenting data is statistics. In statistics, there are three common ways to summarize data with a single number—the mean, the median, and the mode.

The **mean** of a set of data is the arithmetic average. It is found by adding the numbers in the data set and dividing by the number of items in the set.

The **median** is the middle number in a set of data when the data are arranged in numerical order. If there were an even number of data points, the median would be the mean of the two middle numbers.

The **mode** of a set of data is the number. or item that appears most often.

Another number that often is used to describe a set of data is the range. The **range** is the difference between the largest number and the smallest number in a set of data.

A **frequency table** shows how many times each piece of data occurs, usually in a survey. **Table 2** below shows the results of a student survey on favorite color.

Table 2 Student Color Choice		
Color	Tally	Frequency
Red		4
Blue	##	5
Black		2
Green		3
Purple	<del>    </del>	7
Yellow	<del>    </del>	6

Based on the frequency table data, which color is the favorite?

**Example** The speeds (in m/s) for a race car during five different time trials are 39, 37, 44, 36, and 44.

#### To find the mean:

**Step 1** Find the sum of the numbers. 39 + 37 + 44 + 36 + 44 = 200

**Step 2** Divide the sum by the number of items, which is 5.

$$200 \div 5 = 40$$

The mean is 40 m/s.

#### To find the median:

**Step 1** Arrange the measures from least to greatest. 36, 37, 39, 44, 44

**Step 2** Determine the middle measure. 36, 37, 39, 44, 44

The median is 39 m/s.

#### To find the mode:

**Step 1** Group the numbers that are the same together. 44, 44, 36, 37, 39

**Step 2** Determine the number that occurs most in 44, 44, 36, 37, 39

The mode is 44 m/s.

#### To find the range:

**Step 1** Arrange the measures from greatest to least. 44, 44, 39, 37, 36

**Step 2** Determine the greatest and least measures in the set. <u>44</u>, 44, 39, 37, <u>36</u>

**Step 3** Find the difference between the greatest and least measures.

$$44 - 36 = 8$$

The range is 8 m/s.

Practice Problem Find the mean, median, mode, and range for the data set 8, 4, 12, 8, 11, 14, 16.

#### **Use Geometry**

The branch of mathematics that deals with the measurement, properties, and relationships of points, lines, angles, surfaces, and solids is called geometry.

**Perimeter** The **perimeter** (*P*) is the distance around a geometric figure. To find the perimeter of a rectangle, add the length and width and multiply that sum by two, or 2(l + w). To find perimeters of irregular figures, add the length of the sides.

**Example 1** Find the perimeter of a rectangle that is 3 m long and 5 m wide.

**Step 1** You know that the perimeter is 2 times the sum of the width and length.

$$P = 2(3 \text{ m} + 5 \text{ m})$$

**Step 2** Find the sum of the width and length.

$$P = 2(8 \text{ m})$$

**Step 3** Multiply by 2.

$$P = 16 \text{ m}$$

The perimeter is 16 m.

**Example 2** Find the perimeter of a shape with sides measuring 2 cm, 5 cm, 6 cm, 3 cm.

**Step 1** You know that the perimeter is the sum of all the sides.

$$P = 2 + 5 + 6 + 3$$

**Step 2** Find the sum of the sides.

$$P = 2 + 5 + 6 + 3$$

$$P = 16$$

The perimeter is 16 cm.

**Practice Problem** Find the perimeter of a rectangle with a length of 18 m and a width of 7 m.

**Practice Problem** Find the perimeter of a triangle measuring 1.6 cm by 2.4 cm by 2.4 cm.

**Area of a Rectangle** The area (A) is the number of square units needed to cover a surface. To find the area of a rectangle, multiply the length times the width, or  $l \times w$ . When finding area, the units also are multiplied. Area is given in square units.

**Example** Find the area of a rectangle with a length of 1 cm and a width of 10 cm.

**Step 1** You know that the area is the length multiplied by the width.

$$A = (1 \text{ cm} \times 10 \text{ cm})$$

Step 2 Multiply the length by the width. Also multiply the units.

$$A = 10 \text{ cm}^2$$

The area is  $10 \text{ cm}^2$ .

**Practice Problem** Find the area of a square whose sides measure 4 m.

**Area of a Triangle** To find the area of a triangle, use the formula:

$$A = \frac{1}{2}(\text{base} \times \text{height})$$

The base of a triangle can be any of its sides. The height is the perpendicular distance from a base to the opposite endpoint, or vertex.

**Example** Find the area of a triangle with a base of 18 m and a height of 7 m.

**Step 1** You know that the area is  $\frac{1}{2}$  the base times the height.

$$A = \frac{1}{2} (18 \text{ m} \times 7 \text{ m})$$

**Step 2** Multiply  $\frac{1}{2}$  by the product of 18  $\times$  7. Multiply the units.

$$A = \frac{1}{2}(126 \text{ m}^2)$$

$$A = 63 \text{ m}^2$$

The area is  $63 \text{ m}^2$ .

**Practice Problem** Find the area of a triangle with a base of 27 cm and a height of 17 cm.

#### **Circumference of a Circle** The diameter

(d) of a circle is the distance across the circle through its center, and the **radius** (r) is the distance from the center to any point on the circle. The radius is half of the diameter. The distance around the circle is called the **circumference** (C). The formula for finding the circumference is:

$$C = 2\pi r$$
 or  $C = \pi d$ 

The circumference divided by the diameter is always equal to 3.1415926... This nonterminating and nonrepeating number is represented by the Greek letter  $\pi$  (pi). An approximation often used for  $\pi$  is 3.14.

**Example 1** Find the circumference of a circle with a radius of 3 m.

**Step 1** You know the formula for the circumference is 2 times the radius times  $\pi$ .

$$C = 2\pi(3)$$

**Step 2** Multiply 2 times the radius.

$$C = 6\pi$$

**Step 3** Multiply by  $\pi$ .

$$C = 19 \text{ m}$$

The circumference is 19 m.

**Example 2** Find the circumference of a circle with a diameter of 24.0 cm.

**Step 1** You know the formula for the circumference is the diameter times  $\pi$ .

$$C = \pi(24.0)$$

**Step 2** Multiply the diameter by  $\pi$ .

$$C = 75.4 \text{ cm}$$

The circumference is 75.4 cm.

**Practice Problem** Find the circumference of a circle with a radius of 19 cm.

**Area of a Circle** The formula for the area of a circle is:

$$A = \pi r^2$$

**Example 1** Find the area of a circle with a radius of 4.0 cm.

- **Step 1**  $A = \pi (4.0)^2$
- **Step 2** Find the square of the radius.

$$A = 16\pi$$

**Step 3** Multiply the square of the radius by  $\pi$ .

$$A = 50 \text{ cm}^2$$

The area of the circle is 50 cm<sup>2</sup>.

**Example 2** Find the area of a circle with a radius of 225 m.

- **Step 1**  $A = \pi (225)^2$
- **Step 2** Find the square of the radius.

$$A = 50625\pi$$

**Step 3** Multiply the square of the radius by  $\pi$ .

$$A = 158962.5$$

The area of the circle is 158,962 m<sup>2</sup>.

**Example 3** Find the area of a circle whose diameter is 20.0 mm.

**Step 1** You know the formula for the area of a circle is the square of the radius times  $\pi$ , and that the radius is half of the diameter.

$$A = \pi \left(\frac{20.0}{2}\right)^2$$

**Step 2** Find the radius.

$$A = \pi (10.0)^2$$

**Step 3** Find the square of the radius.

$$A = 100\pi$$

**Step 4** Multiply the square of the radius by  $\pi$ .

$$A = 314 \, \text{mm}^2$$

The area is 314 mm<sup>2</sup>.

**Practice Problem** Find the area of a circle with a radius of 16 m.

**Volume** The measure of space occupied by a solid is the **volume** (*V*). To find the volume of a rectangular solid multiply the length times width times height, or  $V = l \times w \times h$ . It is measured in cubic units, such as cubic centimeters (cm<sup>3</sup>).

**Example** Find the volume of a rectangular solid with a length of 2.0 m, a width of 4.0 m, and a height of 3.0 m.

**Step 1** You know the formula for volume is the length times the width times the height.

$$V = 2.0 \,\mathrm{m} \times 4.0 \,\mathrm{m} \times 3.0 \,\mathrm{m}$$

**Step 2** Multiply the length times the width times the height.

$$V = 24 \text{ m}^3$$

The volume is  $24 \text{ m}^3$ .

**Practice Problem** Find the volume of a rectangular solid that is 8 m long, 4 m wide, and 4 m high.

To find the volume of other solids, multiply the area of the base times the height.

**Example 1** Find the volume of a solid that has a triangular base with a length of 8.0 m and a height of 7.0 m. The height of the entire solid is 15.0 m.

**Step 1** You know that the base is a triangle, and the area of a triangle is  $\frac{1}{2}$  the base times the height, and the volume is the area of the base times the height.

$$V = \left[\frac{1}{2} (b \times h)\right] \times 15$$

**Step 2** Find the area of the base.

$$V = \left[\frac{1}{2} (8 \times 7)\right] \times 15$$

$$V = \left(\frac{1}{2} \times 56\right) \times 15$$

**Step 3** Multiply the area of the base by the height of the solid.

$$V = 28 \times 15$$
  
 $V = 420 \text{ m}^3$ 

The volume is 420 m<sup>3</sup>.

**Example 2** Find the volume of a cylinder that has a base with a radius of 12.0 cm, and a height of 21.0 cm.

**Step 1** You know that the base is a circle, and the area of a circle is the square of the radius times  $\pi$ , and the volume is the area of the base times the height.

$$V = (\pi r^2) \times 21$$
  
 $V = (\pi 12^2) \times 21$ 

**Step 2** Find the area of the base.

$$V = 144\pi \times 21$$

$$V = 452 \times 21$$

**Step 3** Multiply the area of the base by the height of the solid.

$$V = 9,490 \text{ cm}^3$$

The volume is  $9,500 \text{ cm}^3$ .

**Example 3** Find the volume of a cylinder that has a diameter of 15 mm and a height of 4.8 mm.

**Step 1** You know that the base is a circle with an area equal to the square of the radius times  $\pi$ . The radius is one-half the diameter. The volume is the area of the base times the height.

$$V = (\pi r^2) \times 4.8$$

$$V = \left[\pi \left(\frac{1}{2} \times 15\right)^2\right] \times 4.8$$

$$V = (\pi 7.5^2) \times 4.8$$

**Step 2** Find the area of the base.

$$V = 56.25\pi \times 4.8$$
  
 $V \approx 176.63 \times 4.8$ 

**Step 3** Multiply the area of the base by the height of the solid.

$$V = 847.8$$

The volume is 847.8 mm<sup>3</sup>.

**Practice Problem** Find the volume of a cylinder with a diameter of 7 cm in the base and a height of 16 cm.

# **Science Applications**

#### **Measure in SI**

The metric system of measurement was developed in 1795. A modern form of the metric system, called the International System (SI), was adopted in 1960 and provides the standard measurements that all scientists around the world can understand.

The SI system is convenient because unit sizes vary by powers of 10. Prefixes are used to name units. Look at **Table 3** for some common SI prefixes and their meanings.

Table 3 Common SI Prefixes			
Prefix	Symbol	Meaning	
kilo-	k	1,000	thousand
hecto-	h	100	hundred
deka-	da	10	ten
deci-	d	0.1	tenth
centi-	С	0.01	hundredth
milli-	m	0.001	thousandth

**Example** How many grams equal one kilogram?

- Step 1 Find the prefix kilo- in Table 3.
- **Step 2** Using **Table 3**, determine the meaning of *kilo-*. According to the table, it means 1,000. When the prefix *kilo*- is added to a unit, it means that there are 1,000 of the units in a "kilounit."
- **Step 3** Apply the prefix to the units in the question. The units in the question are grams. There are 1,000 grams in a kilogram.

**Practice Problem** Is a milligram larger or smaller than a gram? How many of the smaller units equal one larger unit? What fraction of the larger unit does one smaller unit represent?

## **Dimensional Analysis**

**Convert SI Units** In science, quantities such as length, mass, and time sometimes are measured using different units. A process called dimensional analysis can be used to change one unit of measure to another. This process involves multiplying your starting quantity and units by one or more conversion factors. A conversion factor is a ratio equal to one and can be made from any two equal quantities with different units. If 1,000 mL equal 1 L then two ratios can be made.

$$\frac{1,000 \text{ mL}}{1 \text{ L}} = \frac{1 \text{ L}}{1,000 \text{ mL}} = 1$$

One can convert between units in the SI system by using the equivalents in **Table 3** to make conversion factors.

**Example 1** How many cm are in 4 m?

**Step 1** Write conversion factors for the units given. From **Table 3,** you know that 100 cm = 1 m. The conversion factors are

$$\frac{100 \text{ cm}}{1 \text{ m}}$$
 and  $\frac{1 \text{ m}}{100 \text{ cm}}$ 

**Step 2** Decide which conversion factor to use. Select the factor that has the units you are converting from (m) in the denominator and the units you are converting to (cm) in the numerator.

**Step 3** Multiply the starting quantity and units by the conversion factor. Cancel the starting units with the units in the denominator. There are 400 cm in 4 m.

$$4 \text{ m} \times \frac{100 \text{ cm}}{1 \text{ m}} = 400 \text{ cm}$$

**Practice Problem** How many milligrams are in one kilogram? (Hint: You will need to use two conversion factors from Table 3.)

Table 4 Unit System Equivalents		
Type of Measurement	Equivalent	
Length	1 in = 2.54 cm	
	1 yd = 0.91 m	
	1 mi = 1.61 km	
Mass	1  oz = 28.35  g	
and	1  lb = 0.45  kg	
weight*	1 ton (short) = 0.91 tonnes (metric tons)	
	1  lb = 4.45  N	
Volume	$1 \text{ in}^3 = 16.39 \text{ cm}^3$	
	1 qt = 0.95 L	
	1 gal = 3.78 L	
Area	$1 \text{ in}^2 = 6.45 \text{ cm}^2$	
	$1 \text{ yd}^2 = 0.83 \text{ m}^2$	
	$1  \text{mi}^2 = 2.59  \text{km}^2$	
	1 acre = 0.40 hectares	
Temperature	°C = (°F − 32)	
	1.8	
	$K = {}^{\circ}C + 273$	

<sup>\*</sup>Weight is measured in standard Earth gravity.

#### **Convert Between Unit Systems Table 4**

gives a list of equivalents that can be used to convert between English and SI units.

**Example** If a meterstick has a length of 100 cm, how long is the meterstick in inches?

**Step 1** Write the conversion factors for the units given. From **Table 4,** 1 in = 2.54 cm.

$$\frac{1 \text{ in}}{2.54 \text{ cm}}$$
 and  $\frac{2.54 \text{ cm}}{1 \text{ in}}$ 

**Step 2** Determine which conversion factor to use. You are converting from cm to in. Use the conversion factor with cm on the bottom.

**Step 3** Multiply the starting quantity and units by the conversion factor. Cancel the starting units with the units in the denominator. Round your answer to the nearest tenth.

$$100 \, \text{cm} \times \frac{1 \, \text{in}}{2.54 \, \text{cm}} = 39.37 \, \text{in}$$

The meterstick is about 39.4 in long.

**Practice Problem** A book has a mass of 5 lbs. What is the mass of the book in kg?

**Practice Problem** Use the equivalent for in and cm  $(1 \text{ in} = 2.54 \text{ cm}) \text{ to show how } 1 \text{ in}^3 = 16.39 \text{ cm}^3.$ 

## **Precision and Significant Digits**

When you make a measurement, the value you record depends on the precision of the measuring instrument. This precision is represented by the number of significant digits recorded in the measurement. When counting the number of significant digits, all digits are counted except zeros at the end of a number with no decimal point such as 2,050, and zeros at the beginning of a decimal such as 0.03020. When adding or subtracting numbers with different precision, round the answer to the smallest number of decimal places of any number in the sum or difference. When multiplying or dividing, the answer is rounded to the smallest number of significant digits of any number being multiplied or divided.

**Example** The lengths 5.28 and 5.2 are measured in meters. Find the sum of these lengths and record your answer using the correct number of significant digits.

**Step 1** Find the sum.

**Step 2** Round to one digit after the decimal because the least number of digits after the decimal of the numbers being added is 1.

The sum is 10.5 m.

**Practice Problem** How many significant digits are in the measurement 7,071,301 m? How many significant digits are in the measurement 0.003010 g?

**Practice Problem** Multiply 5.28 and 5.2 using the rule for multiplying and dividing. Record the answer using the correct number of significant digits.

#### **Scientific Notation**

Many times numbers used in science are very small or very large. Because these numbers are difficult to work with scientists use scientific notation. To write numbers in scientific notation, move the decimal point until only one non-zero digit remains on the left. Then count the number of places you moved the decimal point and use that number as a power of ten. For example, the average distance from the Sun to Mars is 227,800,000,000 m. In scientific notation, this distance is  $2.278 \times 10^{11}$  m. Because you moved the decimal point to the left, the number is a positive power of ten.

The mass of an electron is about Expressed in scientific notation, this mass is  $9.11 \times 10^{-31}$  kg. Because the decimal point was moved to the right, the number is a negative power of ten.

**Example** Earth is 149,600,000 km from the Sun. Express this in scientific notation.

- **Step 1** Move the decimal point until one non-zero digit remains on the left. 1.496 000 00
- **Step 2** Count the number of decimal places you have moved. In this case, eight.
- **Step 3** Show that number as a power of ten,  $10^8$ .

Farth is  $1.496 \times 10^8$  km from the Sun.

**Practice Problem** How many significant digits are in 149,600,000 km? How many significant digits are in  $1.496 \times 10^{8}$  km?

**Practice Problem** Parts used in a high performance car must be measured to  $7 \times 10^{-6}$  m. Express this number as a decimal.

**Practice Problem** A CD is spinning at 539 revolutions per minute. Express this number in scientific notation.

## **Make and Use Graphs**

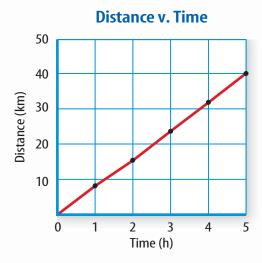
Data in tables can be displayed in a graph—a visual representation of data. Common graph types include line graphs, bar graphs, and circle graphs.

**Line Graph** A line graph shows a relationship between two variables that change continuously. The independent variable is changed and is plotted on the *x*-axis. The dependent variable is observed, and is plotted on the *y*-axis.

**Example** Draw a line graph of the data below from a cyclist in a long-distance race.

Table 5 Bicycle Race Data		
Time (h)	Distance (km)	
0	0	
1	8	
2	16	
3	24	
4	32	
5	40	

- **Step 1** Determine the *X*-axis and *y*-axis variables. Time varies independently of distance and is plotted on the *X*-axis. Distance is dependent on time and is plotted on the *y*-axis.
- **Step 2** Determine the scale of each axis. The *X*-axis data ranges from 0 to 5. The *y*-axis data ranges from 0 to 50.
- **Step 3** Using graph paper, draw and label the axes. Include units in the labels.
- **Step 4** Draw a point at the intersection of the time value on the *X*-axis and corresponding distance value on the *Y*-axis. Connect the points and label the graph with a title, as shown in **Figure 20.**



**Figure 20** This line graph shows the relationship between distance and time during a bicycle ride.

**Practice Problem** A puppy's shoulder height is measured during the first year of her life. The following measurements were collected: (3 mo, 52 cm), (6 mo, 72 cm), (9 mo, 83 cm), (12 mo, 86 cm). Graph this data.

**Find a Slope** The slope of a straight line is the ratio of the vertical change, rise, to the horizontal change, run.

Slope = 
$$\frac{\text{vertical change (rise)}}{\text{horizontal change (run)}} = \frac{\text{change in } y}{\text{change in } x}$$

**Example** Find the slope of the graph in **Figure 20.** 

**Step 1** You know that the slope is the change in *y* divided by the change in *x*.

$$\mathsf{Slope} = \frac{\mathsf{change} \, \mathsf{in} \, y}{\mathsf{change} \, \mathsf{in} \, x}$$

**Step 2** Determine the data points you will be using. For a straight line, choose the two sets of points that are the farthest apart.

Slope = 
$$\frac{(40-0) \text{ km}}{(5-0) \text{ h}}$$

**Step 3** Find the change in *y* and *x*.

Slope = 
$$\frac{40 \text{ km}}{5 \text{h}}$$

**Step 4** Divide the change in *y* by the change in *x*.

$$Slope = \frac{8 \text{ km}}{h}$$

The slope of the graph is 8 km/h.

**Bar Graph** To compare data that does not change continuously you might choose a bar graph. A bar graph uses bars to show the relationships between variables. The *x*-axis variable is divided into parts. The parts can be numbers such as years, or a category such as a type of animal. The  $\gamma$ -axis is a number and increases continuously along the axis.

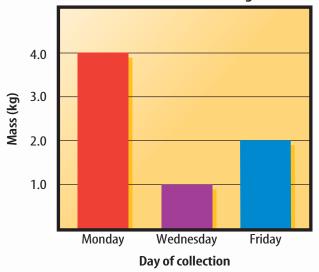
**Example** A recycling center collects 4.0 kg of aluminum on Monday, 1.0 kg on Wednesday, and 2.0 kg on Friday. Create a bar graph of this data.

**Step 1** Select the *x*-axis and *y*-axis variables. The measured numbers (the masses of aluminum) should be placed on the y-axis. The variable divided into parts (collection days) is placed on the x-axis.

**Step 2** Create a graph grid like you would for a line graph. Include labels and units.

**Step 3** For each measured number, draw a vertical bar above the x-axis value up to the y-axis value. For the first data point, draw a vertical bar above Monday up to 4.0 kg.

**Aluminum Collected During Week** 



**Practice Problem** Draw a bar graph of the gases in air: 78% nitrogen, 21% oxygen, 1% other gases.

**Circle Graph** To display data as parts of a whole, you might use a circle graph. A circle graph is a circle divided into sections that represent the relative size of each piece of data. The entire circle represents 100%, half represents 50%, and so on.

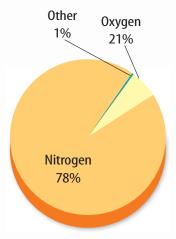
**Example** Air is made up of 78% nitrogen, 21% oxygen, and 1% other gases. Display the composition of air in a circle graph.

**Step 1** Multiply each percent by 360° and divide by 100 to find the angle of each section in the circle.

$$78\% \times \frac{360^{\circ}}{100} = 280.8^{\circ}$$
$$21\% \times \frac{360^{\circ}}{100} = 75.6^{\circ}$$
$$1\% \times \frac{360^{\circ}}{100} = 3.6^{\circ}$$

**Step 2** Use a compass to draw a circle and to mark the center of the circle. Draw a straight line from the center to the edge of the circle.

**Step 3** Use a protractor and the angles you calculated to divide the circle into parts. Place the center of the protractor over the center of the circle and line the base of the protractor over the straight line.



**Practice Problem** Draw a circle graph to represent the amount of aluminum collected during the week shown in the bar graph to the left.

# **Formulas**

#### **Chapter 1 The Nature of Science**

```
density = mass/volume
Kelvin = ^{\circ}Celsius + 273
% Error = [(Accepted value - Experimental value)/Accepted value] \times 100
```

#### **Chapter 3 Motion, Acceleration, and Forces**

```
average speed = total distance/total time
acceleration = (final velocity - initial velocity)/(final time - initial time)
```

#### **Chapter 4 The Laws of Motion**

```
acceleration = net force/mass
net force = mass \times acceleration
gravitational force = mass \times (acceleration due to gravity)
weight = mass \times 9.8 m/s<sup>2</sup>
momentum (p) = mass \times velocity
```

#### **Chapter 5 Energy**

```
kinetic energy =\frac{1}{2} mass \times (velocity)<sup>2</sup>
gravitational potential energy (GPE) = mass 	imes 9.8 m/s^2 	imes height
mechanical energy = gravitational potential energy + kinetic energy
```

#### **Chapter 6 Work and Machines**

```
work = force \times distance
power = work/time
power = energy transferred/time
mechanical advantage = output force/input force
efficiency \% = (\text{output work/input work}) \times 100
Ideal mechanical advantage of a lever = length of input arm/length of output arm
Ideal mechanical advantage of a wheel and axle = radius of wheel/radius of axle
Ideal mechanical advantage of an inclined plane = length of slope/height of slope
```

#### **Chapter 9 Heat and States of Matter**

```
change in thermal energy = mass \times change in temperature \times specific heat
Q = m \times (T_{final} - T_{initial}) \times C_{p}
latent heat of melting = mass \times heat of fusion
latent heat of vaporization = mass \times heat of vaporization
```

## **Math Skill Handbook**

#### **Chapter 10 Waves**

```
wave speed = wavelength \times frequency
frequency = number of wavelengths/time
wavelength = wave speed/frequency
```

#### **Chapter 11 Sound and Light**

index of refraction = speed of light in a vacuum/speed of light in a substance or n = c/v

#### **Chapter 13 Electricity**

```
electric current = voltage difference/resistance
electric power = current \times voltage difference
electric energy = power \times time
```

## **EXTRA** Math Problems

For help and hints with these problems, visit Math Practice at gpescience.com.

#### **Chapter 1** The Nature of Science

- 1. How many centimeters are in four meters?
- 2. How many deciliters are in 500 mL?
- 3. How many liters are in 2540 cm<sup>3</sup>?
- 4. A young child has a mass of 40 kg. What is the mass of the child in grams?
- 5. Iron has a density of 7.9 g/cm<sup>3</sup>. What is the mass in kg of an iron statue that has a volume of 5.4 L?
- 6. A 2-L bottle of soda has a volume of 2000 cm<sup>3</sup>. What is the volume of the bottle in cubic meters?
- **7.** A big summer movie has a running time of 96 minutes. What is the movie's running time in seconds?
- **8.** The temperature in space is approximately 3 K. What is this temperature in degrees Celsius?
- **9.** The x-axis of a certain graph is distance traveled in meters and the y-axis is time in seconds. Two points are plotted on this graph with coordinates (2, 43) and (5, 68). What is the elapsed time between the two points?
- 10. A circle graph has labeled segments of: 57%, 21%, 13%, and 6%. What percentage does the unlabeled segment have?

#### **Chapter 2** Science, Technology, and Society

- 11. A car can travel 14 km on 1 L of gasoline. What percentage of its fuel efficiency does another car have if it travels 10 km on 1 L of gasoline?
- 12. What is the fuel efficiency of a car if it gets 45 percent of the fuel efficiency of another car that travels 15 km on 1 L of gasoline?
- **13.** If new information technology causes a three percent reduction in the 40,000,000 HIV infections worldwide, how many people would be infected?

- **14.** A circle graph shows the comparative effects of five new technologies. The circle graph has segments labeled 45 percent, 32 percent, 12 percent, and 3 percent. What is the correct label of the fifth seament?
- 15. Data from a new Web site takes 17 min to download. How many seconds does it take?
- **16.** If a new internet connection reduces a download time of 17 min by 85 percent, how much time (in minutes and seconds) will it take now?
- 17. Because of a new health center in a town, the cases of influenza are 25 percent fewer. If the town usually has 300 cases per month, how many cases should you expect during the next month?
- 18. If a person can sell 10 computers per day and a new technology allows her to triple her sales, how many computers can she expect to sell the next day?
- 19. If it normally takes 45 min to travel to a nearby town using an older train, but a new technologically advanced train can make the trip in one-third of the time, how long will the trip take?
- **20.** A technologically advanced engine runs at twice the efficiency of an older engine. If the older engine allows a car to travel at a fuel efficiency of 8 km/L, what is the fuel efficiency of the advanced engine?

## **Chapter 3** Motion, Acceleration, and

- 21. John rides his bike 2.3 km to school. After school, he rides an additional 1.4 km to the mall in the opposite direction. What is his total distance traveled?
- **22.** A squirrel runs 4.8 m across a lawn, stops, then runs 2.3 m back in the opposite direction. What is the squirrel's displacement from its starting point?

- **23.** An ant travels 75 cm in 5 s. What was the ant's speed?
- **24.** It took you 6.5 h to drive 550 km. What was your speed?
- 25. A bus leaves at 9 A.M. with a group of tourists. They travel 350 km before they stop for lunch. Then they travel an additional 250 km until the end of their trip at 3 P.M. What was the average speed of the bus?
- **26.** Halfway through a cross-country meet, a runner's speed is 4 m/s. In the last stretch, she increases her speed to 7 m/s. What is her change in speed?
- **27.** It takes a car one minute to go from rest to 30 m/s. What is the acceleration of this car?
- 28. You are running at a speed of 10 km/h and hit a patch of mud. Two seconds later your speed is 8 km/h. What is your acceleration in units of m/s<sup>2</sup>?
- **29.** During a tug-of-war, Team A is applying a force of 5000 N while Team B is applying a force of 8000 N. What is the net force applied to the rope?
- **30.** You are in a car traveling an average speed of 60 km/h. The total trip is 240 km. How long does the trip take?
- **31.** You are riding in a train that is traveling at a speed of 120 km/h. How long will it take to travel 950 km?
- **32.** A car goes from rest to a speed of 90 km/h in 10 s. What is the car's acceleration in m/s<sup>2</sup>?
- **33.** A cart rolling at a speed of 10 m/s comes to a stop in 2 s. What is the cart's acceleration?

#### **Chapter 4** The Laws of Motion

- **34.** A 85-kg mass has an acceleration of 5.5 m/s<sup>2</sup>. What is the net force applied?
- **35.** A 3200-N force is applied to a 160-kg mass. What is the acceleration of the mass?
- **36.** A 2-kg object is dropped from a height of 1000 m. What is the force of air resistance on the object when it reaches terminal velocity?
- 37. How much force is needed to lift a 25-kg mass?

- **38.** If you are pushing on a box with a force of 20 N and there is a force of 7 N on the box due to sliding friction, what is the net force on the box?
- **39.** The acceleration due to gravity on the moon is about 1.6 m/s<sup>2</sup>. If you weigh 539 N on Earth, how much would you weigh on the moon?
- **40.** If a 5000-kg mass is moving at a speed of 43 m/s, what is its momentum?
- **41.** How fast must a 50-kg mass travel to have a momentum of 1500 kg m/s?
- **42.** What is the net force on a 4000-kg car that doubles its speed from 15 m/s to 30 m/s over 10 seconds?
- **43.** A book with a mass of 1 kg is sliding on a table. If the frictional force on the book is 5 N, calculate the book's acceleration. Is it speeding up or slowing down?
- **44.** What is the weight of a person with a mass of 80 kg?
- **45.** A car with a mass of 1,200 kg has a speed of 30 m/s. What is the car's momentum?

#### **Chapter 5** Energy

- **46.** What is the kinetic energy of a 5-kg object moving at 7 m/s?
- **47.** An object has kinetic energy of 600 J and a speed of 10 m/s. What is its mass?
- **48.** If you throw a 0.4-kg ball at a speed of 20 m/s, what is the ball's kinetic energy?
- **49.** A rollercoaster car moving around a high turn has 100,000 J of GPE and 23,000 J of KE. What is its mechanical energy?
- **50.** If you have a mass of 80 kg and you are standing on a platform 3 m above the ground, what is your gravitational potential energy?
- **51.** A car is traveling at 30 m/s with a kinetic energy of 900 kJ. What is its mass?
- 52. At top of a hill, a rollercoaster has 67,500 J of kinetic energy and 290,000 J of potential energy. Gradually the roller coaster comes to a stop due to friction. If the roller coaster has 30,000 J of potential when it stops, how much heat energy is generated by friction from the top of the hill until it stops?

- 53. A 2-kg book is moved from a shelf that is 2 m off the ground to a shelf that is 1.5 m off the ground. What is its change in GPE?
- **54.** A system has a total mechanical energy of 350 J and kinetic energy of 220 J. What is its potential energy?
- **55.** An object held in the air has a GPE of 470 J. The object then is dropped. Halfway down, what is the object's kinetic energy?
- **56.** A car with a mass of 900 kg is traveling at a speed of 25 m/s. What is the kinetic energy of the car in joules?
- **57.** What is the gravitational potential energy of a diver with a mass of 60 kg who is 10 m above the water?
- **58.** If your weight is 500 N, and you are standing on a floor that is 20 m above the ground, what is your gravitational potential energy?

#### **Chapter 6** Work and Machines

- **59.** When moving a couch, you exert a force of 400 N and push it 4 m. How much work have you done?
- **60.** How much work is needed to lift a 50-kg weight to a shelf 3 m above the floor?
- **61.** By applying a force of 50 N, a pulley system can lift a box with a mass of 20 kg. What is the mechanical advantage of the pulley system?
- **62.** How much energy do you save per hour if you replace a 60-watt lightbulb with a 55-watt lightbulb?
- **63.** Suppose you supply energy to a machine at a rate of 700 W and that the machine converts 560 J into heat every second. At what rate does the machine do work?
- **64.** You exert a force of 200 N on a machine over a distance of 0.3 m. If the machine moves an object a distance of 0.5 m, how much force does the machine exert on the object? Assume friction can be ignored.
- **65.** What is the efficiency of a machine if you do work on the machine at a rate of 1200 W and the machine does work at a rate of 300 W?

- **66.** What is the IMA of a seesaw with a 1.6-m effort arm and a 1.2-m resistance arm?
- **67.** What is the IMA of a wheel with a radius of 0.35 m and an axle radius of 0.04 m?
- **68.** An inclined plane has an IMA of 1.5 and a height of 2.0 m. How long is this inclined plane?
- **69.** What power is used by a machine to perform 800 J of work in 25 s?
- **70.** A person pushes a box up a ramp that is 3 m long, and 1 m high. If the box has a mass of 20 kg, and the person pushes with a force of 80 N, what is the efficiency of the ramp?
- **71.** A first class lever has a mechanical advantage of 5. How large would a force need to be to lift a rock with a mass of 100 kg?

#### **Chapter 7** The Earth-Moon-Sun System

- 72. Earth's diameter is 12,714 km from pole to pole and 12,756 km at the equator. How much less is Earth's diameter from pole to pole than that at the equator?
- 73. Earth's circumference is 40,075 km at the equator and 40,008 km through the two poles. How much greater is Earth's circumference around the equator?
- 74. Earth's average density is 5.52 g/cm<sup>3</sup>. If the Moon's average density is 3.31 g/cm<sup>3</sup>, what percentage of Earth's density is the Moon's density?
- **75.** If a day on Earth lasts 23 h and 56 min, how many minutes are in one day?
- **76.** Earth is one AU (149,600,000 km) from the Sun. If Jupiter is 5.2 AUs from the Sun, how many kilometers is Jupiter from the Sun?
- 77. If Earth rotates 15° each hour, how many degrees will it rotate in three hours?
- **78.** Earth is tilted 23.5°. If the Sun is 50° above the southern horizon when it is directly over the equator, how high in the sky will the Sun be on the first day of summer?
- **79.** If the Sun has a diameter of 1,392,000 km and is about 400 times larger than the Moon, what is the approximate diameter of the Moon?

- **80.** If there are 29.5 days in one synodic month, how many synodic months are there in one year of 365 days?
- **81.** The South Pole-Aitken Basin on the Moon is 12 km deep and 2,500 km wide. How many times wider is the basin than it is deep?

#### **Chapter 8** The Solar System

- **82.** What fraction of a complete orbit (360°) would a planet move through if its H.L. changes from 32° to 302°?
- **83.** What fraction of a complete orbit (360°) would a planet move through if its H.L. changes from 152° to 242°?
- **84.** Earth's atmospheric pressure is 101.3 kPa. What is atmospheric pressure on the surface of Titan if it is 1.5 times that of Earth?
- **85.** What is the atmospheric pressure on the surface of Mars if it is 0.6 percent of Earth's?
- **86.** If the atmospheric pressure of Triton's atmosphere is 0.002 percent of Earth's, what is the atmospheric pressure on the surface of Triton?
- **87.** If a planet has an H.L. of 73°, what percentage of the total orbit (360°) would this represent?
- **88.** If the diameters of Earth and Uranus are 12,756 km and 51,118 km respectively, approximately how many Earths could fit across Uranus's diameter?
- 89. The volume of sphere is  $4/3(\pi r^3)$ . If the radius of Earth is 6,378 km and the radius of Jupiter is 71,492, how many Earths would fit inside Jupiter?
- **90.** The volume of sphere is  $4/3(\pi r^3)$ . If the radius of Mars is 3,394 km and the radius of Earth is 6,378 km, what percentage of Earth's volume is Mars's volume?
- **91.** On average, Earth is 150 million km (1 AU) from the Sun. If Saturn is 9.53 AU from the Sun, what is the distance from the Sun to Saturn?
- **92.** If Venus takes 0.62 years to orbit the Sun and Saturn takes 29.42 years to orbit the Sun, how many times will Venus orbit the Sun during each orbit of Saturn?

**93.** If Earth is tilted 23.5° and Uranus is tilted 97.9°, how many times greater is the axial tilt of Uranus than that of Earth?

#### **Chapter 9** Heat and States of Matter

- **94.** Water has a specific heat of 4184 J/(kg K). How much energy is needed to increase the temperature of a kilogram of water 5°C?
- **95.** The temperature of a block of iron, which has a specific heat of 450 J/(kg K), increases by 3 K when 2700 J of energy are added to it. What is the mass of this block of iron?
- **96.** How much energy is needed to heat 1 kg of sand, which has a specific heat of 664 J/(kg K), from 30°C to 50°C?
- **97.** 1 kg of water (specific heat = 4184 J/(kg K)) is heated from freezing (0°C) to boiling (100°C). What is the change in thermal energy?
- 98. A concrete statue (specific heat = 600 J/(kg K)) sits in sunlight and warms up to 40°C. Overnight, it cools to 15°C and loses 90,000 J of thermal energy. What is its mass?
- **99.** A glass of water has temperature of 70°C. What is its temperature in K?
- 100. A substance with a mass of 10 kg loses 106.5 kJ of heat when its temperature drops 15°C. What is this substance's specific heat?
- **101.** Air is cooled from room temperature (25°C) to 100 K. What is the temperature change in K?
- 102. To remove 800 J of heat from a refrigerator, the compressor in the refrigerator does 500 J of work. How much heat is released into the surrounding room?
- **103.** How much heat is needed to raise the temperature of 100 g of water by 50 K, if the specific heat of water is 4,184 J/kg K?
- 104. A sample of an unknown metal has a mass of 0.5 kg. Adding 1,985 J of heat to the metal raises its temperature by 10 K. What is the specific heat of the metal?

#### **Chapter 10** Waves

**105.** What is the wavelength of a wave with a frequency of 0.4 kHz traveling at 16 m/s?

- **106.** Two waves are traveling in the same medium with a speed of 340 m/s. What is the difference in frequency of the waves if the one has a wavelength of 5 m and the other has a wavelength of 0.2 m?
- **107.** Transverse wave A has an amplitude of 7 cm. This wave constructively interferes with wave B. While the two waves overlap, the amplitude of the resulting wave is 10 cm. What is the amplitude of wave B?
- **108.** What is the wavelength of a wave with a frequency of 5 Hz traveling at 15 m/s?
- **109.** What is the velocity of a wave that has a wavelength of 6 m and a frequency of 3 Hz?
- 110. A ray of light hits a mirror at an angle of 35° to the normal. What is the angle of the reflected ray to the normal?
- 111. A wave has a wavelength of 250 cm and a frequency of 4 Hz. What is its speed?
- 112. A wave has a frequency of 5.6 MHz. What is the frequency of this wave in Hz?
- **113.** A light ray strikes a mirror and is reflected. The angle between the incident and reflected rays is 86°. What is the angle of the incident ray to the normal?
- **114.** What is the frequency of a wave with a wavelength of 7 m traveling at 21 m/s?

#### **Chapter II** Sound and Light

- 115. A sound wave with a frequency of 440 Hz travels in steel with a speed of 5200 m/s. What is the wavelength of the sound wave?
- **116.** A wave traveling in water has a wavelength of a 750 m and a frequency of 2 Hz. How fast is this wave moving?
- 117. At 0°C sound travels through air with a speed of about 331 m/s and through aluminum with a speed of 4877 m/s. How many times longer is the wavelength of a sound wave in aluminum compared to the wavelength of a sound wave in air if both waves have the same frequency?

- 118. The speed of sound in air at 0°C is 331 m/s, and at 20°C is 344 m/s. What is the percentage change in the speed of sound at 20°C compared to 0°C?
- **119.** The wreck of the *Titanic* is at a depth of about 3800 m. A sonar unit on a ship above the Titanic emits a sound wave that travels at a speed of 1500 m/s. How long does it take a sound wave reflected from the Titanic to return to the ocean surface?
- **120.** A sonar unit on a ship emits a sound wave. The echo from the ocean floor is detected two seconds later. If the speed of sound in water is 1500 m/s, how deep is the ocean beneath the ship?
- **121.** A tsunami travels across the ocean at a speed of 500 km/h. If the distance between the wave crests is 200 km, what is the frequency of the wave?
- **122.** A light ray strikes a plane mirror. The angle between the light ray and the surface of the mirror is 25°. What angle does the reflected ray make with the normal?
- **123.** If the index of refraction of the mineral rock salt is 1.52, and the speed of light in a vacuum is 300,000 km/s, what is the speed of light in rock salt?
- **124.** In the human eye, there are about 7,000,000 cone cells distributed over an area of 5 cm<sup>2</sup>. If cone cells are evenly distributed over this region, how many cone cells are distributed over an area of 2 cm<sup>2</sup>? Express your answer in scientific notation.
- **125.** The magnification of a mirror or lens equals the image size divided by the object size. If a plant cell with a diameter of 0.0035 mm is magnified so that the diameter of the image is 0.028 cm, what is the magnification?
- **126.** Light enters the human eye through the pupil. In the dark, the pupil is dilated and has a diameter of about 1 cm. The Keck telescope has a mirror with a diameter of 10 m. If both the pupil and the Keck mirror are circles, what is the ratio of the area of the Keck telescope mirror to the area of a dilated human pupil?

**127.** A light source is placed a distance of 1.2 m from a concave mirror on the optical axis. The reflected light rays are parallel and form a light beam. What is the focal length of the mirror?

#### **Chapter 12** Earth's Internal Processes

- **128.** How long after an earthquake will a seismograph 3,000 km away from the epicenter record S-waves that travel at 3.6 km/s?
- **129.** If it takes 48 min and 20 s for P-waves traveling at 6.0 km/s to reach and be recorded by a seismograph, how far away is the epicenter?
- 130. If S-waves lag behind P-waves by 1 min 52 s for every 1000 km of distance from the earthquake epicenter, how far away from the earthquake epicenter is a seismograph that measures a time-lag of 5 min 30 s between the arrivals of P-waves and S-waves.?
- 131. With a P-wave-S-wave lag time of 1 min 52 sec, how much difference between the arrival times of P-waves and S-waves would be measured at 3,000 km? At 3,500 km?
- **132.** If surface waves travel at 3.2 km/s, when would you expect them to arrive at a seismograph that is 2,500 km distant from the earthquake epicenter?
- 133. If S-waves travel at 3.6 km/s and P-waves travel at 6.0 km/s through Earth's crust, what percentage of the speed of P-waves would you expect S-waves to travel at other depths inside Earth?
- **134.** The volume of a cone is  $\frac{1}{3}\pi r^2 h$ . If Paricutín is 424 m high and has a base 2.8 km across, what is the volume of the cinder cone?
- **135.** If two plates diverge at a rate of 1.3 cm/year, how much farther apart in kilometers will the two plates be after 200 million years?
- **136.** How many times faster are plates moving at 7.3 cm/year than are plates moving at 1.3 cm/year?
- 137. The volume of a sphere is  $4/3(\pi r^3)$ . The radius of Earth is 6,378 km, and the radius of its core (including both outer and inner cores) is 3,486 km. What are the volumes of both? What percentage of the total volume of Earth is its core?

#### **Chapter 13** Electricity

- **138.** A circuit has a resistance of 4  $\Omega$ . What voltage difference will cause a current of 1.4 A to flow in the circuit?
- **139.** How many amperes of current will flow in a circuit if the voltage difference is 9 V and the resistance in the circuit is 3  $\Omega$ ?
- **140.** If a voltage difference of 3 V causes a 1.5 A current to flow in a circuit, what is the resistance in the circuit?
- **141.** The current in an appliance is 3 A and the voltage difference is 120 V. How much power is being supplied to the appliance?
- **142.** What is the current into a microwave oven that requires 700 W of power if the voltage difference is 120 V?
- **143.** What is the voltage difference in a circuit that uses 2420 W of power if 11 A of current flows into the circuit?
- **144.** How much energy is used when a 110 kW appliance is used for 3 hours?
- **145.** A television has a power rating of 210 W. If the television uses 1.68 kWh of energy, for how long has the television been on?
- **146.** How much does it cost to light six 100-W lightbulbs for six hours if the price of electrical energy is \$0.09/kWh?
- **147.** An electric clothes dryer uses 4 kW of electric power. How long did it take to dry a load of clothes if electric power costs \$0.09/kWh, and the cost of using the dryer was \$0.27?
- **148.** What is the resistance of a lightbulb that draws 0.5 amp of current when plugged into a 120-V outlet?
- **149.** How much current flows through a 100-W lightbulb that is plugged into a 120-V outlet?
- **150.** Eight amps of current flow through a hair dryer connected to a 120-V outlet. How much electrical power does the hair dryer use?
- **151.** Compare the electrical energy that is used by a 100-W lightbulb that burns for 10 h, and a 1,200-W hair dryer that is used for 15 min.

#### **Chapter 14** Magnetism

- **152.** How many turns are in the secondary coil of a step-down transformer that reduces a voltage from 900 V to 300 V and has 15 turns in the primary coil?
- **153.** A step-down transformer reduces voltage from 2400 V to 120 V. What is the ratio of the number of turns in the primary coil to the number of turns in the secondary coil of the transformer?
- **154.** The current produced by an AC generator switches direction twice for each revolution of the coil. How many times does a 110-Hz alternating current switch direction each second?
- **155.** What is the output voltage from a step-down transformer with 200 turns in the primary coil and 100 turns in the secondary coil if the input voltage was 750 V?
- **156.** What is the output voltage from a step-up transformer with 25 turns in the primary coil and 75 turns in the secondary coil if the input voltage was 120 V?
- **157.** How many turns are in the primary coil of a step-down transformer that reduces a voltage from 400 V to 100 V and has 80 turns in the secondary coil?
- **158.** How many turns are in the secondary coil of a step-up transformer that increases voltage from 30 V to 150 V and has seven turns in the primary coil?
- **159.** The coil of a 60-Hz generator makes 60 revolutions each second. How many revolutions does the coil make in five minutes?
- **160.** If a generator coil makes 6000 revolutions in two minutes, how many revolutions does it make each second?

#### **Chapter 15** Electromagnetic Radiation

- **161.** Express the number 20,000 in scientific notation.
- **162.** An electromagnetic wave has a wavelength of 0.054 m. What is the wavelength in scientific notation?

- **163.** Earth is about 4,500,000,000 years old. Express this number in scientific notation.
- **164.** The speed of electromagnetic waves in air is 300,000 km/s. What is the frequency of electromagnetic waves that have a wavelength of  $5 \times 10^{-3} \, \text{km}$ ?
- **165.** The speed of radio waves in water Is about  $2.26 \times 10^5$  km/s. What is the frequency of radio waves that have a wavelength of 3.0 km?
- **166.** Radio waves with a frequency of 125,000 Hz have a wavelength of 1.84 km when traveling in ice. What is the speed of the radio waves in ice?
- **167.** Some infrared waves have a frequency of 10,000,000,000,000 Hz. Express this frequency in scientific notation.
- **168.** An infrared wave has a frequency of  $1 \times 10^{13}$  Hz and a wavelength of  $3 \times 10^{-5}$  m. Express this wavelength as a decimal number.
- 169. An AM radio station broadcasts at a frequency of 620 kHz. Express this frequency in Hz using scientific notation.
- **170.** An FM radio station broadcasts at a frequency of 101 MHz. Express this frequency in Hz using scientific notation.

#### **Chapter 16** Energy Sources

- **171.** A gallon of gasoline contains about 2800 g of gasoline. If burning one gram of gasoline releases about 48 kJ of energy, how much energy is released when a gallon of gasoline is burned? (1 kJ = 1000 J)
- **172.** An automobile engine converts the energy released by burning gasoline into mechanical energy with an efficiency of about 25%. If burning 1 kg of gasoline releases about 48,000 kJ of energy, how much mechanical energy is produced by the engine when 1 kg of gasoline is burned?
- **173.** You heat a cup of water in a 750-W microwave oven for 40 s, and warm the water by 20°C. If it takes about 20 kJ of energy to raise the temperature of a cup of water by 20°C, what is the efficiency of the microwave oven?

- **174.** On average, solar energy strikes Earth's surface with an intensity of about 200 W/m<sup>2</sup>. If solar cells are 10% efficient, how large an area would have to be covered by solar cells to generate enough electrical power to light a 100-W lightbulb?
- 175. What is the overall efficiency of a hydroelectric plant if the process of falling water turning a turbine is 80% efficient, the turbine spinning an electric generator is 95% efficient, and the transmission through power lines is 90% efficient?
- 176. When a certain  $^{235}_{92}$ U nucleus is struck by a neutron, it forms the two nuclei  $^{91}_{36}$ Kr and  $^{142}_{56}$ Ba. How many neutrons are emitted when this occurs?
- **177.** A nuclear reactor contains 100,000 kg of enriched uranium. About 4% of the enriched uranium is the isotope uranium-235. What is the mass of uranium-235 in the reactor core?
- **178.** Suppose the number of uranium-235 nuclei that are split doubles at each stage of a chain reaction. If the chain reaction starts with one nucleus split in the first stage, how many nuclei will have been split after six stages?
- 179. From 1970 to 1995 the carbon dioxide concentration in Earth's atmosphere increased from about 325 parts per million to about 360 parts per million. What was the percentage change in the concentration of carbon dioxide?
- **180.** About 85% of the energy used in the U.S. comes from fossil fuels. How many times greater is the amount of energy used from fossil fuel than the amount used from all other energy sources?

#### **Chapter 17** Weather and Climate

- **181.** If a snowy surface reflects 90 percent of the solar radiation that strikes it and bare soil reflects 30 percent, how many times more solar radiation is reflected from a snowy surface than from bare soil?
- **182.** The amount of rainfall over five days is 4 cm, 2 cm, 0.4 cm, 0.2 cm, and 1.3 cm. What is the average rainfall per day?

- **183.** Air pressure at Earth's surface is 101.3 kPa. What is the air pressure at 16 km if it is  $\frac{1}{10}$  the air pressure at Earth's surface?
- **184.** Much of northern Florida receives 1,300 mm of rain on average per year and the southern part of the Everglades receives 1,650 mm of rain on average per year. What percentage is the rainfall in northern Florida of the rainfall in the southern part of the Everglades?
- **185.** If the tilt of Earth's axis has varied from 21.5° to 24.5° over time, what is the value of the range of Earth's axial tilt?
- **186.** Air pressure at Earth's surface is 101.3 kPa. If air pressure in an average car tire is equal to two atmospheres, what is the pressure in an average car tire?
- **187.** Most of Earth's atmosphere is within 30 km of Earth's surface. If Earth's atmosphere extends about 10,000 km above Earth's surface, what percentage of the atmosphere's depth contains most of Earth's atmosphere?
- **188.** If a tornado travels at 50 km/h and cuts a path of destruction 10 km long, how many minutes did it take to do this?
- **189.** If there have been eight glacial periods during the past 200,000 years, what is the rate at which these have occurred?
- 190. The three main gases in Earth's atmosphere are nitrogen—78 percent, oxygen—21 percent, and argon and trace gases—1 percent. If a circle graph were drawn to represent these data, how many degrees would represent each section?

#### **Chapter 18** Classification of Matter

191. Two solutions, one with a mass of 450 g and the other with a mass of 350 g, are mixed. A chemical reaction occurs and 125 g of solid crystals are produced that settle on the bottom of the container. What is the mass of the remaining solution?

- **192.** Carbon reacts with oxygen to form carbon dioxide according to the following equation:  $C + O_2 \rightarrow CO_2$ . When 120 g of carbon reacts with oxygen, 440 g of carbon dioxide are formed. How much oxygen reacted with the carbon?
- 193. Salt water is distilled by boiling it and condensing the vapor. After distillation, 1,164 g of water have been collected and 12 g of salt are left behind in the original container. What was the original mass of the salt water?
- **194.** Calcium carbonate, CaCO<sub>3</sub>, decomposes according to the reaction:  $CaCO_3 \rightarrow CaO +$ CO<sub>2</sub>. When 250 g of CaCO<sub>3</sub> decompose completely, the mass of CaO is 56% of the mass of the products of this reaction. What is the mass of CO<sub>2</sub> produced?
- **195.** Water breaks down into hydrogen gas and oxygen gas according to the reaction:  $2H_2O \rightarrow 2H_2 + O_2$ . In this reaction the mass of oxygen produced is eight times greater than the mass of hydrogen produced. If 36 g of water form hydrogen and oxygen gas, what is the mass of hydrogen gas produced?
- **196.** The size of particles in a solution is about 1 nm (1 nm = 0.000000001 m). Write 0.000000001 min scientific notation.
- **197.** A chemical reaction produces two new substances, one with a mass of 34 g and the other with a mass of 39 g. What was the total mass of the reactants?
- **198.** The human body is about 65% oxygen. If a person has a mass of 75.0 kg, what is the mass of oxygen in their body?
- 199. A 112-g serving of ice cream contains 19 g of fat. What percentage of the serving is fat?
- **200.** The mass of the products produced by a chemical reaction is measured. The reaction is repeated five times, with the same mass of reactants used each time. The measured product masses are 50.17 g, 50.12 g, 50.17 g, 50.10 g, and 50. 14 g. What is the average of these measurements?

#### **Chapter 19** Properties of Atoms and the Periodic Table

- **201.** Boron has a mass number of 11 and an atomic number of 5. How many neutrons are in a boron atom?
- **202.** A magnesium atom has 12 protons and 12 neutrons. What is its mass number?
- 203. Iodine-127 has a mass number of 127 and 74 neutrons. What percentage of the particles in an iodine-127 nucleus are protons?
- **204.** How many neutrons are in an atom of phosphorus-31?
- **205.** What is the ratio of neutrons to protons in the isotope radium-234?
- **206.** About 80% of all magnesium atoms are magnesium-24, about 10% are magnesium-25, and about 10% are magnesium-26. What is the average atomic mass of magnesium?
- **207.** The half-life of the radioactive isotope rubidium-87 is 48,800,000,000 years. Express this half-life in scientific notation.
- **208.** The radioactive isotope nickel-63 has a half-life of 100 years. How much of a 10.0-g sample of nickel-63 is left after 300 years?
- **209.** A sample of the radioactive isotope cobalt-62 is prepared. The sample has a mass of 1.00 g. After three minutes, the mass of cobalt-62 remaining is 0.25 g. What is the half-life of cobalt-62?
- **210.** A neutral phosphorus atom has 15 electrons. How many electrons are in the third energy level?

#### **Chapter 20** Earth Materials

- **211.** If oxygen makes up 46.6 percent of the mass of Earth's crust and silicon makes up 27.7 percent, what is the total percent of the crust's mass for oxygen and silicon?
- **212.** If oxygen and silicon make up 74.3 percent of the mass of Earth's crust, what percent of this percentage is silicon's percentage?
- **213.** How many total atoms of aluminum and oxygen combined make up one molecule of corundum  $(Al_2O_3)$ ?

- **214.** What is the ratio of silicon to oxygen in a molecule of olivine ((Mg, Fe)<sub>2</sub>SiO<sub>4</sub>)?
- 215. Other than the common eight elements that make up Earth's crust, all other elements make up only 1.5 percent. If oxygen makes up 46.6 percent of Earth's crust, how many times greater is the amount of oxygen in Earth's crust than those other elements.
- **216.** The Mohs scale of hardness consists of ten categories, each associated with a mineral standard. How many categories are between hardness 7–quartz and hardness 2–gypsum?
- **217.** The volume of sphere is  $4/3 \pi r^3$ . If a particle of gravel has a radius of 2 mm and a sand grain has a radius of 1 mm, how much bigger is the volume of the gravel?
- **218.** If a sedimentary rock has a porosity of 15 percent, how much volume do the mineral grains and cement take up?
- **219.** If you have a halite cube that measures 4 cm on each side, what is the total surface area of the cube?
- **220.** What is the ratio of oxygen atoms to potassium atoms in one molecule of K-feldspar, (KAISiO<sub>o</sub>)?

#### **Chapter 21** Earth's Changing Surface

- **221.** If soil erosion averages 2.5 cm per year and the average soil profile is 3.2 m thick with 40 percent of topsoil, how long will it take for the topsoil to erode away?
- **222.** The average soil profile in your area is 2.1 m thick. Topsoil erodes at 2.0 cm per year. What percent of the soil profile is topsoil if it erodes in 14 years?
- 223. Soil erosion in your area averages 3.5 cm per year. The average soil profile is 3.7 m thick and 35 percent of that is topsoil. Soil replacement through weathering is 0.2 cm per year. How long will it take for the topsoil to erode?
- **224.** Observations taken at the mouth of a stream include a flow rate of 120 m<sup>3</sup>/s and a suspended sediment load of 1.8 kg/m<sup>3</sup>. How many kilograms of sediment potentially could drop out of this stream each day?

- 225. Observations taken at the mouth of a stream include a flow rate of 85 m<sup>3</sup>/s and a suspended sediment load of 1.6 kg/m<sup>3</sup>. How many kilograms of sediment potentially could drop out of this stream each day?
- 226. Suppose a community with a human population of 800 has a water consumption rate of 900 L per person per day. This community relies on an aquifer that is thought to contain 1.2 billion L of water. Assuming no change in average water consumption or significant recharge of the aquifer, how many years will this water supply last?
- **227.** An aquifer is 400 km in length, 185 km in width, and 80 km thick. Sampling of the aquifer material shows it has an average porosity of 15 percent. What is the volume of porosity?
- 228. An aquifer with dimensions of 350 km in length, 175 km in width, and 65 km thick. Sampling of the aquifer material shows it has an average porosity of 10 percent. What is the volume of porosity?
- **229.** If three half-lives for an isotope have passed, what fraction of the original isotope would be present in the igneous rock?
- **230.** If the half-life of an isotope is 12,000 years and the amount of the isotope present in the rock is only  $\frac{1}{16}$  of the original amount present, how old is the igneous rock containing the isotope?

#### **Chapter 22** Chemical Bonds

- **231.** What is the formula of the compound formed when ammonium ions,  $NH_{4'}^+$  and phosphate ions,  $PO_4^{3-}$ , combine?
- **232.** Show that the sum of positive and negative charges in a unit of calcium chloride (CaCl<sub>2</sub>) equals zero.
- 233. What is the formula for iron(III) oxide?
- **234.** How many hydrogen atoms are in three molecules of ammonium phosphate,  $(NH_4)_3PO_4$ ?
- **235.** The overall charge on the polyatomic phosphate ion,  $PO_4^{3-}$ , is 3-. What is the oxidation number of phosphorus in the phosphate ion?

- **236.** The overall charge on the polyatomic dichromate ion,  $Cr_2O_7^{2-}$ , is 2—. What is the oxidation number of chromium in this polyatomic ion?
- 237. What is the formula for lead(IV) oxide?
- 238. What is the formula for potassium chlorate?
- 239. What is the formula for carbon tetrachloride?
- **240.** What percentage of the mass of a sulfuric acid molecule,  $H_2SO_4$ , is sulfur?

#### **Chapter 23** Chemical Reactions

- **241.** Lithium reacts with oxygen to form lithium oxide according to the equation:  $4\text{Li} + \text{O}_2 \rightarrow 2\text{Li}_2\text{O}$ . If 27.8 g of Li react completely with 32.0 g of  $\text{O}_2$ , how many grams of  $\text{Li}_2\text{O}$  are formed?
- **242.** What coefficients balance the following equation:  $Zn(OH)_2 + _H_3PO_4 \rightarrow _Zn_3(PO_4)_2 + _H_2O?$
- **243.** Aluminum hydroxide,  $Al(OH)_3$ , decomposes to form aluminum oxide,  $Al_2O_3$ , and water according to the reaction:  $2Al(OH)_3 \rightarrow Al_2O_3 + 3H_2O$ . If 156.0 g of  $Al(OH)_3$  decompose to from 102.0 g of  $Al_2O_3$ , how many grams of  $H_2O$  are formed?
- **244.** In the following balanced chemical reaction one of the products is represented by the symbol X: BaCO<sub>3</sub> + C + H<sub>2</sub>O  $\rightarrow$  Ba(OH)<sub>2</sub> + H<sub>2</sub>O + 2X. What is the formula for the compound represented by X?
- **245.** When propane,  $C_3H_8$ , is burned, carbon dioxide and water vapor are produced according to the following reaction:  $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ . How much propane is burned if 160.0 g of  $O_2$  are used and 132.0 g of  $CO_2$  and 72.0 g of  $H_2O$  are produced?
- 246. Increasing the temperature usually causes the rate of a chemical reaction to increase. If the rate of a chemical reaction doubles when the temperature increases by 10°C, by what factor does the rate of reaction increase if the temperature increases by 30°C?

- **247.** When acetylene gas,  $C_2H_2$ , is burned, carbon dioxide and water are produced. Find the coefficients that balance the chemical equation for the combustion of acetylene:  $C_2H_2 + O_2 \rightarrow CO_2 + H_2O$ .
- **248.** What coefficients balances the following equation:  $_{CS_2} + _{O_2} \rightarrow _{CO_2} + _{SO_2}$ ?
- 249. When methane, CH<sub>4</sub>, is burned, 50.1 kJ of energy per gram are released. When propane, C<sub>3</sub>H<sub>8</sub>, is burned, 45.8 kJ of energy are released. If a mixture of 1 g of methane and 1 g of propane is burned, how much energy is released per gram of mixture?
- **250.** A chemical reaction produces 0.050 g of a product in 0.18 s. In the presence of a catalyst, the reaction produces 0.050 g of the same product in 0.007 s. How much faster is the rate of reaction in the presence of the enzyme?

#### **Chapter 24** Solutions, Acids, and Bases

- **251.** A cup of orange juice contains 126 mg of vitamin C and 1/2 cup of strawberries contain 42 mg of vitamin C. How many cups of strawberries contain as much vitamin C as one cup of orange juice?
- **252.** What is the total surface area of a 2-cm cube?
- **253.** A cube has 2-cm sides. If it is split in half, what is the total surface area of the two pieces?
- **254.** At 20°C, the solubility in water of potassium bromide, KBr, is 65.3 g/100 mL. What is the maximum amount of potassium bromide that will dissolve in 237 mL of water?
- 255. At 20°C, the solubility of sodium chloride, NaCl, in water is 35.9 g/100 mL. If the maximum amount of sodium chloride is dissolved in 500 mL of water at 20°C, the mass of the dissolved sodium chloride is what percentage of the mass of the solution?
- **256.** The difference between the pH of an acidic solution and the pH of pure water is 3. What is the pH of the solution?

- 257. The pH of rain that fell over a region had measured values of 4.6, 5.1, 4.8, 4.5, 4.5, 4.9, 4.7, and 4.8. What was the mean value of the measured pH?
- **258.** If 5.5% of 473.0 mL of vinegar is acetic acid, how many milliliters of acetic acid are there?
- 259. Write the balanced chemical equation for the neutralization of H<sub>2</sub>SO<sub>4</sub>, sulfuric acid, by KOH, potassium hydroxide.
- **260.** Write the balanced chemical equation for the neutralization of HBr, hydrobromic acid, by Al(OH)<sub>3</sub>, aluminum hydroxide.

#### **Chapter 25** Nuclear Changes

- **261.** How many protons are in the nucleus  $^{81}_{36}$ Kr?
- **262.** How many neutrons are in the nucleus  ${}_{26}^{56}$ Fe?
- **263.** What is the ratio of neutrons to protons in the nucleus <sup>241</sup><sub>95</sub>Am ?
- **264.** How many alpha particles are emitted when the nucleus  $^{222}_{86}$ Rn decays to  $^{218}_{84}$ Po?
- **265.** How many beta particles are emitted when the nucleus  ${}^{40}_{19}$ K decays to the nucleus  ${}^{40}_{20}$ Ca?
- 266. An alpha particle is the same as the helium nucleus <sup>4</sup><sub>2</sub>He. What nucleus is produced when the nucleus  $^{226}_{88}$ Ra decays by emitting an alpha particle?
- **267.** How long will it take a sample of  $^{194}_{84}$ Po to decay to 1/8 of its original amount if <sup>194</sup><sub>84</sub>Po has a half-life of 0.7 s?
- **268.** The half-life of  $^{131}_{53}$ I is 8.04 days. How much time would be needed to reduce 1 g of  $^{131}_{53}$ I to 0.25 g?
- 269. A sample of radioactive carbon-14 sample has decayed to 12.5% of its original amount. If the half-life of carbon-14 is 5730 years, how old is this sample?
- **270.** A sample of  ${}_{17}^{38}$ Cl is observed to decay to 25% of the original amount in 74.4 minutes. What is the half-life of <sup>38</sup><sub>17</sub>Cl?

#### **Chapter 26** Stars and Galaxies

- **271.** If the focal length of a telescope's objective is 900 mm and the focal length of its eyepiece is 10 mm, what is the magnifying power of this telescope?
- **272.** If the focal length of a telescope's objective is 700 mm and the magnifying power of the telescope is 40 times, what is the focal length of an eyepiece?
- **273.** If it takes 25 days for a sunspot to travel once around the Sun, about how many days would it take to travel across the face of the Sun?
- **274.** If a solar prominence blasts material from the Sun at a speed of 600 km/s, how long in hours and minutes would it take for material to arrive at Earth 150 million km away?
- 275. How many times larger in area is a 250-mm-diameter objective than a 100-mm diameter objective?
- **276.** How many times larger in area is an 8-m-diameter objective than a 5-m-diameter objective?
- **277.** How many times larger is an elliptical galaxy that is nine million light-years across than one that is 3,000 light-years across?
- 278. A telescope's objective has a focal length of 1,200 mm. It is used with two eyepieces that have focal lengths of 12 mm and 18 mm. How many times greater is the magnifying power of the telescope when the 12-mm eyepiece is used?
- **279.** A telescope's objective has a focal length of 1500 mm. It is used with two eyepieces that have focal lengths of 20 mm and 12.5 mm. What percentage of the magnifying power obtained using the 12.5-mm eyepiece is achieved using the 20-mm eyepiece?
- **280.** If the age of the universe was thought to be 20 billion years, but is now considered to be 13.7 billion years, how much younger is the universe thought to be now?

# **Rocks**

Rocks		
Rock Type	Rock Name	Characteristics
Igneous (intrusive)	Granite	Large mineral grains of quartz, feldspar, hornblende, and mica. Usually light in color.
	Diorite	Large mineral grains of feldspar, hornblende, and mica. Less quartz than granite. Intermediate in color.
	Gabbro	Large mineral grains of feldspar, augite, and olivine. No quartz. Dark in color.
<b>Igneous</b> (extrusive)	Rhyolite	Small mineral grains of quartz, feldspar, hornblende, and mica, or no visible grains. Light in color.
	Andesite	Small mineral grains of feldspar, hornblende, and mica or no visible grains. Intermediate in color.
	Basalt	Small mineral grains of feldspar, augite, and possibly olivine or no visible grains. No quartz. Dark in color.
	Obsidian	Glassy texture. No visible grains. Volcanic glass. Fracture looks like broken glass.
	Pumice	Frothy texture. Floats in water. Usually light in color.
Sedimentary	Conglomerate	Coarse grained. Gravel or pebble-size grains.
(detrital)	Sandstone	Sand-sized grains 1/16 to 2 mm.
	Siltstone	Grains are smaller than sand but larger than clay.
	Shale	Smallest grains. Often dark in color. Usually platy.
Sedimentary (chemical or organic)	Limestone	Major mineral is calcite. Usually forms in oceans and lakes. Often contains fossils.
	Coal	Forms in swampy areas. Compacted layers of organic material, mainly plant remains.
Sedimentary (chemical)	Rock Salt	Commonly forms by the evaporation of seawater.
Metamorphic (foliated)	Gneiss	Banding due to alternate layers of different minerals, of different colors. Parent rock often is granite.
	Schist	Parallel arrangement of sheetlike minerals, mainly micas. Forms from different parent rocks.
	Phyllite	Shiny or silky appearance. May look wrinkled. Common parent rocks are shale and slate.
	Slate	Harder, denser, and shinier than shale. Common parent rock is shale.
Metamorphic	Marble	Calcite or dolomite. Common parent rock is limestone.
(nonfoliated)	Soapstone	Mainly of talc. Soft with greasy feel.
	Quartzite	Hard with interlocking quartz crystals. Common parent rock is sandstone.

# **Minerals**

Minerals					
Mineral (formula)	Color	Streak	Hardness	Breakage Pattern	Uses and Other Properties
<b>Graphite</b> (C)	black to gray	black to gray	1–1.5	basal cleavage (scales)	pencil lead, lubricants for locks, rods to control some small nuclear reactions, battery poles
<b>Galena</b> (PbS)	gray	gray to black	2.5	cubic cleavage perfect	source of lead, used for pipes, shields for X rays, fishing equipment sinkers
Hematite (Fe <sub>2</sub> O <sub>3</sub> )	black or reddish- brown	reddish- brown	5.5-6.5	irregular fracture	source of iron; converted to pig iron, made into steel
<b>Magnetite</b> (Fe <sub>3</sub> O <sub>4</sub> )	black	black	6	conchoidal fracture	source of iron, attracts a magnet
<b>Pyrite</b> (FeS <sub>2</sub> )	light, brassy, yellow	greenish- black	6-6.5	uneven fracture	fool's gold
<b>Talc</b> (Mg <sub>3</sub> Si <sub>4</sub> O <sub>10</sub> (OH) <sub>2</sub> )	white, greenish	white	1	cleavage in one direction	used for talcum powder, sculptures, paper, and tabletops
<b>Gypsum</b> (CaSO <sub>4</sub> •2H <sub>2</sub> 0)	colorless, gray, white, brown	white	2	basal cleavage	used in plaster of paris and dry wall for building construction
<b>Sphalerite</b> (ZnS)	brown, reddish- brown, greenish	light to dark brown	3.5-4	cleavage in six directions	main ore of zinc; used in paints, dyes, and medicine
Muscovite (KAI <sub>3</sub> Si <sub>3</sub> O <sub>10</sub> (OH) <sub>2</sub> )	white, light gray, yellow, rose, green	colorless	2–2.5	basal cleavage	occurs in large, flexible plates; used as an insulator in electrical equipment, lubricant
Biotite (K(Mg,Fe) <sub>3</sub> (AlSi <sub>3</sub> O <sub>10</sub> ) (OH) <sub>2</sub> )	black to dark brown	colorless	2.5–3	basal cleavage	occurs in large, flexible plates
<b>Halite</b> (NaCl)	colorless, red, white, blue	colorless	2.5	cubic cleavage	salt; soluble in water; a preservative

# **Minerals**

Minerals					
Mineral (formula)	Color	Streak	Hardness	Breakage Pattern	Uses and Other Properties
Calcite (CaCO <sub>3</sub> )	colorless, white, pale blue	colorless, white	3	cleavage in three directions	fizzes when HCI is added; used in cements and other building materials
<b>Dolomite</b> (CaMg (CO <sub>3</sub> ) <sub>2</sub> )	colorless, white, pink, green, gray, black	white	3.5–4	cleavage in three directions	concrete and cement; used as an ornamental building stone
Fluorite (CaF <sub>2</sub> )	colorless, white, blue, green, red, yellow, purple	colorless	4	cleavage in four directions	used in the manufacture of optical equipment; glows under ultraviolet light
Hornblende (CaNa) <sub>2-3</sub> (Mg,AI, Fe) <sub>5</sub> -(AI,Si) <sub>2</sub> Si <sub>6</sub> O <sub>22</sub> (OH) <sub>2</sub> )	green to black	gray to white	5–6	cleavage in two directions	will transmit light on thin edges; 6-sided cross section
Feldspar (KAISi <sub>3</sub> O <sub>8</sub> ) (NaAI Si <sub>3</sub> O <sub>8</sub> ), (CaAI <sub>2</sub> Si <sub>2</sub> O <sub>8</sub> )	colorless, white to gray, green	colorless	6	two cleavage planes meet at 90° angle	used in the manufacture of ceramics
Augite ((Ca,Na) (Mg,Fe,Al) (Al,Si) <sub>2</sub> O <sub>6</sub> )	black	colorless	6	cleavage in two directions	square or 8-sided cross section
Olivine ((Mg,Fe) <sub>2</sub> SiO <sub>4</sub> )	olive, green	none	6.5–7	conchoidal fracture	gemstones, refractory sand
Quartz (SiO <sub>2</sub> )	colorless, various colors	none	7	conchoidal fracture	used in glass manufacture, electronic equipment, radios, computers, watches, gemstones

# **Physical Science Reference Tables**

#### **Standard Units**

Symbol	Name	Quantity
m	meter	length
kg	kilogram	mass
Pa	pascal	pressure
K	kelvin	temperature
mol	mole	amount of a substance
J	joule	energy, work, quantity of heat
S	second	time
C	coulomb	electric charge
V	volt	electric potential
Α	ampere	electric current
$\Omega$	ohm	resistance

#### **Physical Constants and Conversion Factors**

Acceleration due to gravity	g	9.8 m/s/s or m/s <sup>2</sup>
Avogadro's Number	$N_A$	$6.02 \times 10^{23}$ particles per mole
Electron charge	е	$1.6 \times 10^{-19}$ C
Electron rest mass	$m_{e}$	$9.11  imes 10^{-31}  \mathrm{kg}$
Gravitation constant	G	$6.67  imes 10^{-11}   ext{N}  imes  ext{m}^2/ ext{kg}^2$
Mass-energy relationship		1 u (amu) = $9.3 \times 10^2  \text{MeV}$
Speed of light in a vacuum	C	$3.00 \times 10^8 \mathrm{m/s}$
Speed of sound at STP	331 m/s	
Standard Pressure	1 atmosph	nere
	101.3 kPa	
	760 Torr o	r mmHg
	14.7 lb/in	2

#### Wavelengths of Light in a Vacuum

Violet	$4.0-4.2\times10^{-7}\mathrm{m}$
Blue	$4.2 - 4.9 \times 10^{-7} \mathrm{m}$
Green	$4.9 - 5.7 \times 10^{-7} \mathrm{m}$
Yellow	$5.7 - 5.9 \times 10^{-7} \mathrm{m}$
Orange	$5.9 - 6.5 \times 10^{-7} \mathrm{m}$
Red	$6.5 - 7.0 \times 10^{-7} \mathrm{m}$

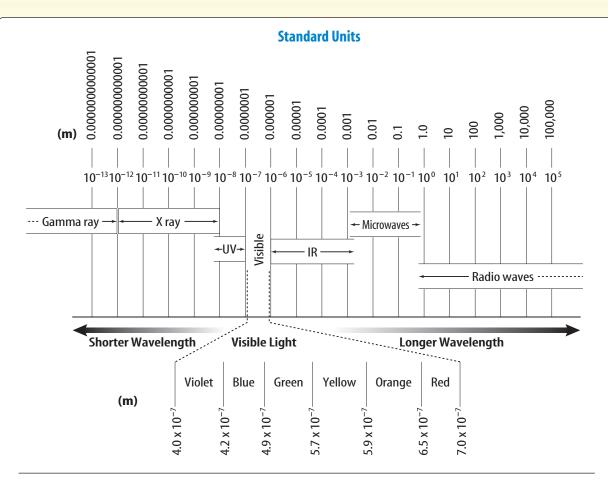
## The Index of Refraction for Common Substances

$$(\lambda = 5.9 \times 10^{-7} \,\mathrm{m})$$

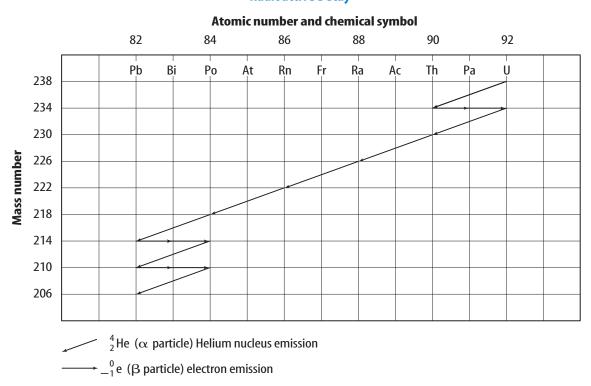
Air	1.00
Alcohol	1.36
Canada Balsam	1.53
Corn Oil	1.47
Diamond	2.42
Glass, Crown	1.52
Glass, Flint	1.61
Glycerol	1.47
Lucite	1.50
Quartz, Fused	1.46
Water	1.33

#### **Heat Constants**

	Specific Heat (average) (kJ/kg $\times$ °C) (J/g $\times$ °C)	Melting Point (°C)	Boiling Point (°C)	Heat of Fusion (kJ/kg) (J/g)	Heat of Vaporization (kJ/kg) (J/g)
Alcohol (ethyl)	2.43 (liq.)	<b>—117</b>	79	109	855
Aluminum	0.90 (sol.)	660	2467	396	10500
Ammonia	4.71 (liq.)	<del>-78</del>	-33	332	1370
Copper	0.39 (sol.)	1083	2567	205	4790
Iron	0.45 (sol.)	1535	2750	267	6290
Lead	0.13 (sol.)	328	1740	25	866
Mercury	0.14 (liq.)	-39	357	11	295
Platinum	0.13 (sol.)	1772	3827	101	229
Silver	0.24 (sol.)	962	2212	105	2370
Tungsten	0.13 (sol.)	3410	5660	192	4350
Water (solid)	2.05 (sol.)	0	_	334	_
Water (liquid)	4.18 (liq.)	_	100	_	_
Water (vapor)	2.01 (gas)	_	_	_	2260
Zinc	0.39 (sol.)	420	907	113	1770



#### **Radioactive Decay**

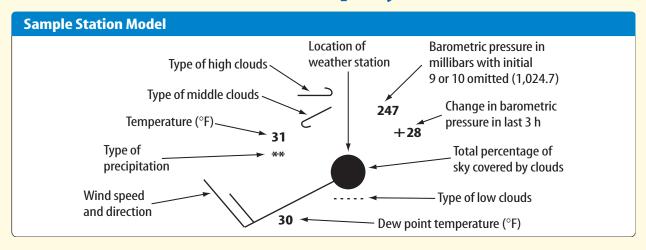


#### PERIODIC TABLE OF THE ELEMENTS Gas Columns of elements are called groups. Elements in the same group have similar chemical properties. Liquid 1 Solid Element -Hydrogen Hydrogen **Synthetic Atomic number** State of 1 1 2 matter н Symbol 1.008 **Atomic mass** 1.008 The first three symbols tell you the state of matter of the element at room Lithium Beryllium temperature. The fourth symbol Be 🗆 2 identifies elements that are not present Li 6.941 9.012 in significant amounts on Earth. Useful amounts are made synthetically. Magnesium Sodium 11 12 9 3 3 5 6 7 8 4 Na Mg L 22.990 24.305 Vanadium Chromium Potassium Calcium Scandium Titanium Manganese Iron Cobalt 20 21 22 23 24 25 26 27 19 4 ٧ K Sc L Ti Cr Mn Fe Ca Co 39.098 40.078 44.956 47.867 50.942 51.996 54.938 58.933 55.845 Rubidium Strontium Yttrium Zirconium Niobium Molybdenum Technetium Ruthenium Rhodium 45 37 40 42 43 38 39 41 44 0 5 Rb Sr γ Zr Nb Мо Tc Ru Rh 85.468 87.62 88.906 91.224 92.906 95.94 (98)101.07 102.906 **Osmium** Cesium Barium Lanthanum Hafnium Tantalum Tungsten Rhenium Iridium 72 55 56 73 75 76 f 77 6 W Cs Ba La Hf Ta Re 0s Ir 180.948 132.905 137.327 138.906 178.49 183.84 186.207 190.23 192.217 Francium Radium Actinium Rutherfordium Dubnium **Bohrium** Hassium Meitnerium Seaborgium 108 💿 105 87 88 89 104 106 107 109 7 (0) Fr Ra Ac Rf Db Bh Hs Mt Sg (277)(223)(226)(227)(261)(262)(266)(264)(268)The number in parentheses is the mass number of the longest-lived isotope for that element. Rows of elements are called periods. Atomic number increases across a period. Cerium Praseodymium Samarium Neodymium Promethium 61 💿 60 58 59 62 Lanthanide Pr Nd Pm Ce Sm series 140.116 140.908 144.24 (145)150.36 The arrow shows where these elements would fit into the Neptunium **Thorium** Protactinium Uranium Plutonium periodic table. They are moved 90 91 92 93 94 (0) (0) to the bottom of the table to **Actinide** Th Pa U Np Pu save space. series 232.038 231.036 238.029 (237)(244)

## Reference Handbook

Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium	
63 <b>Eu</b>	64 <b>Gd</b>	65 <b>Tb</b>	66	67 <b>—</b>	68 <b>—</b> Er	69 Tm	<sup>70</sup> <b>□</b>	71	
<b>EU</b> 151.964	<b>GG</b> 157.25	158.925	<b>Dy</b> 162.500	<b>по</b> 164.930	<b>Er</b> 167.259	168.934	173.04	<b>Lu</b> 174.967	/
Americium		5 1 11	6 116 1	F1					ľ
95 (o)	Curium 96	Berkelium 97	Californium 98 💿	Einsteinium 99	Fermium 100	Mendelevium 101	Nobelium 102	Lawrencium 103 🕝	
Am $^{\smile}$	Cm <sup>©</sup>	Bk <sup>©</sup>	Cf O	Es	Fm <sup>©</sup>	Md <sup>©</sup>	No <sup>©</sup>	Lr <sup>©</sup>	
(243)	(247)	(247)	(251)	(252)	(257)	(258)	(259)	(262)	

# **Weather Map Symbols**



Sample Plotted Report at Each Station						
Precipitation	Wind Spec and Direct			Some Types of High Clouds		
<b>≡</b> Fog	O calm		O No cover	Scattered cirrus		
★ Snow	∕ 1–2 kn	nots	① 1/10 or less	Dense cirrus in patches		
• Rain	✓ 3–7 kn	nots	2/10 to 3/10	Veil of cirrus covering entire sky		
Thunderstorm	√ 8–12 k	knots	<b>4/10</b>	Cirrus not covering entire sky		
• Drizzle	13–17	knots	<b>1</b> –			
	18-22	knots	6/10			
	23-27	knots	7/10			
	48-52	knots	<ul><li>Overcast with openings</li></ul>			
	1 knot = 1.852	2 km/h	<ul><li>Completely overcast</li></ul>			
Some Types of Mid	dle Clouds	Some	Types of Low Clouds	Fronts and Pressure Systems		
Thin alto	ostratus		Cumulus of fair weather	(H) or High Center of high- or (L) or Low low-pressure system		
Thick alt	ostratus	$\checkmark$	Stratocumulus	Cold front		
Thin alto in patch			Fractocumulus of bad weather	Warm front		
Thin alto in bands			Stratus of fair weather	Occluded front		
				Stationary front		

#### Science

A multilingual science glossary at gpescience.com includes Arabic, Bengali, Chinese, English, Haitian Creole, Hmong, Korean, Portuguese, Russian, Tagalog, Urdu, and Vietnamese.

#### Cómo usar el glosario en español:

- 1. Busca el término en inglés que desees encontrar.
- 2. El término en español, junto con la definición, se encuentran en la columna de la derecha.

#### **Pronunciation Key**

Use the following key to help you sound out words in the glossary.

<b>a</b> b <b>a</b> ck (BAK)	ewfood (FEWD)
<b>ay</b> d <b>a</b> y (DAY)	yoopure (PYOOR)
ah father (FAH thur)	<b>yew</b> fe <b>w</b> (FYEW)
owflower (FLOW ur)	uhcomma (CAH muh)
arcar (CAR)	<b>u</b> (1 <b>con)</b> r <b>u</b> b (RUB)
eless (LES)	shshelf (SHELF)
eeleaf (LEEF)	chnature (NAY chur)
ihtrip (TRIHP)	<b>gg</b> ift (GIHFT)
i (i 1 con 1 e)idea (i DEE uh)	<b>jg</b> em (JEM)
<b>oh</b> g <b>o</b> (GOH)	ingsing (SING)
awsoft (SAWFT)	<b>zh</b> vi <b>si</b> on (VIH zhun)
ororbit (OR buht)	<b>k</b> ca <b>k</b> e (KAYK)
oycoin (COYN)	sseed, cent (SEED, SENT)
<b>oo</b> foot (FOOT)	<b>zz</b> one, rai <b>s</b> e (ZOHN, RAYZ)

#### **English**

A

#### **Español**

- **absolute dating:** process of assigning a precise numerical age to an organism, object, or event, based on an absolute reference. (p. 669)
- **acceleration:** rate of change of velocity; can be calculated by dividing the change in the velocity by the time it takes the change to occur. (p. 76)
- **accuracy:** compares a measurement to the real or accepted value. (p. 14)
- **acid:** any substance that produces hydrogen ions, H<sup>+</sup>, in a water solution. (p. 764)
- **activation energy:** the minimum amount of energy needed to start a reaction (p. 735)
- agricultural biotechnology: scientific techniques, such as genetic engineering, used to increase farm crop yields and nutritional values of foods by creating, modifying, or improving plants, animals, and microorganisms. (p. 45)
- **air resistance:** force that opposes the motion of objects that move through the air. (p. 85)
- **alpha particle:** particle consisting of two protons and two neutrons that is emitted from a decaying atomic nucleus. (p. 791)
- **alternating current (AC):** electric current that reverses its direction of flow in a regular pattern. (p. 442)
- **amplitude:** maximum distance a wave causes the particles in a medium to move from the rest position. (p. 298)

- datación absoluta: proceso de asignar una edad numérica precisa a un organismo, objeto o evento, basado en una referencia absoluta. (p. 669)
- **aceleración:** tasa de cambio de la velocidad; se calcula dividiendo el cambio en la velocidad por el tiempo que toma para que ocurra el cambio. (p. 76)
- **exactitud:** comparación de una medición con el valor real o aceptado. (p. 14)
- **ácido:** sustancia que produce iones de hidrógeno, H<sup>+</sup>, en una solución de agua. (p. 764)
- energía de activación: cantidad mínima de energía necesaria para comenzar una reacción. (p. 735)
- biotecnología agrícola: técnicas científicas, como la ingeniería genética, utilizadas para incrementar la producción de las cosechas de las granjas y los valores nutricionales de los alimentos al crear, modificar o mejorar las plantas, animales y microorganismos. (p. 45)
- **resistencia del aire:** fuerza que se opone al movimiento de los objetos que se mueven por el aire. (p. 85)
- partícula alfa: partícula compuesta por dos protones y dos neutrones y que es emitida por un núcleo atómico en descomposición. (p. 791)
- **corriente alterna (CA):** corriente eléctrica que invierte su dirección de flujo en un patrón regular. (p. 442)
- amplitud: distancia máxima a la que una onda causa que las partículas en un medio salgan de su posición de reposo. (p. 298)

aqueous solution/biomass

Solución acuosa/biomasa

- **aqueous solution:** a solution in which water is the solvent. (p. 753)
- **aquifer:** rock unit that transmits water through its pore space. (p. 664)
- **asteroids:** rocky solar system objects of widely varying size usually found between the orbits of Mars and Jupiter in an area called the asteroid belt. (p. 236)
- **asthenosphere:** weaker, semi-solid, plasticlike layer beneath Earth's lithosphere on which lithospheric plates move. (p. 372)
- **astronomical unit:** about 150 million km, which equals the average distance from Earth to the Sun; used to measure distances within the solar system. (p. 220)
- **atom:** the smallest particle of an element that still retains the properties of the element. (p. 589)
- **atomic number:** number of protons in an atom's nucleus. (p. 585)
- **average atomic mass:** weighted-average mass of the mixture of an element's isotopes. (p. 587)
- **average speed:** total distance an object travels divided by the total time it takes to travel that distance. (p. 72)

- **Solución acuosa:** solución en la que el agua es el solvente. (p. 753)
- **Acuífero:** unidad rocosa que conduce agua a través de su espacio poroso. (p. 664)
- **Asteroides:** objetos rocosos del sistema solar que varían ampliamente en tamaño y usualmente se encuentran entre las órbitas de Marte y Júpiter en un área llamada el cinturón de asteroides. (p. 236)
- **astenosfera:** capa débil, semisólida, similar al plástico que se encuentra por debajo de la litosfera terrestre en la cual se mueven las placas litosféricas. (p. 372)
- unidad astronómica: cerca de 150 millones de km, lo cual equivale a la distancia promedio de la tierra al sol; utilizada para medir distancias entre el sistema solar. (p. 220)
- **átomo:** la partícula más pequeña de un elemento que mantiene las propiedades del elemento. (p. 589)
- **número atómico:** número de protones en el núcleo de un átomo. (p. 585)
- masa atómica promedio: masa de peso promedio resultado de la mezcla de los isótopos de un elemento. (p. 587)
- **velocidad promedio:** distancia que recorre un objeto dividida por el tiempo que dura en recorrer dicha distancia. (p. 72)

B

- **balanced chemical equation:** chemical equation with the same number of atoms of each element on both sides of the equation. (p. 726)
- **balanced forces:** forces on a object that combine to give a zero net force and do not change the motion of the object. (p. 82)
- **base:** any substance that forms hydroxide ions, OH<sup>-</sup>, in a water solution. (p. 766)
- **beta particle:** electron that is emitted from a decaying atomic nucleus. (p. 793)
- **bias:** occurs when a scientist's expectations change how the results of an experiment are viewed. (p. 10)
- **big bang theory:** theory that about 13.7 billion years ago, the entire universe was contained in a single point that began expanding outward. (p. 837)
- **binary compound:** compound that is composed of two elements. (p. 703)
- biomass: renewable organic matter from plants and animals, such as wood and animal manure, that can be burned to provide heat. (p. 506)

- **ecuación química Fnceada:** ecuación química con el mismo número de átomos de cada elemento en los dos lados de la ecuación. (p. 726)
- **fuerzas equilibradas:** fuerzas en un objeto que se combinan para dar una fuerza neta de cero y no cambiar el movimiento del objeto. (p. 82)
- **base:** sustancia que forma iones de hidróxido, OH<sup>-</sup>, en una solución de agua. (p. 766)
- **partícula beta:** electrón emitido por un núcleo atómico en descomposición. (p. 793)
- **predisposición:** ocurre cuando las expectativas de un científico cambian la forma en que son vistos los resultados de un experimento. (p. 10)
- **teoría de la gran explosión:** teoría que hace cerca de 13.7 mil millones años, el universo entero fue contenido en un solo punto que comenzó a ampliarse hacia fuera. (p. 837)
- **compuesto binario:** compuesto conformado por dos elementos. (p. 703)
- biomasa: materia orgánica renovable proveniente de plantas y animales, tales como madera y estiércol animal, que puede ser incinerada para producir calor. (p. 506)

#### biosphere/chemical reaction

biosfera/reacción química

**biosphere:** all living organisms and the environments in which they live. (p. 529)

**bubble chamber:** radiation detector, consisting of a container of superheated liquid under high pressure, that is used to detect the paths of charged particles. (p. 797)

**biosfera:** todos los organismos vivos y los ambientes en los cuales viven. (p. 529)

**cámara de burbujas:** detector de radiación que consiste de un contenedor de un líquido sobrecalentado a alta presión, usado para detectar la trayectoria de las partículas cargadas. (p. 797)



**carrier wave:** specific frequency that a radio station is assigned and uses to broadcast signals. (p. 469)

**catalyst:** substance that speeds up a chemical reaction without being permanently changed itself. (p. 740)

**cathode-ray tube:** sealed vacuum tube that produces one or more beams of electrons that produce an image when they strike the coating on the inside of a TV screen. (p. 472)

**cementation:** sedimentary rock-forming process in which minerals precipitate out of water and fill the spaces between clasts. (p. 625)

**centripetal acceleration:** acceleration of an object toward the center of a curved or circular path. (p. 110)

**centripetal force:** a net force that is directed toward the center of a curved or circular path. (p. 110)

**chain reaction:** ongoing series of fission reactions. (p. 802)

**charging by contact:** process of transferring charge between objects by touching or rubbing. (p. 395)

**charging by induction:** process of rearranging electrons on a neutral object by bringing a charged object close to it. (p. 396)

**chemical bond:** force that holds atoms together in a compound. (p. 694)

**chemical change:** change of one substance into a new substance. (p. 564)

**chemical equation:** shorthand method to describe chemical reactions using chemical formulas and other symbols. (p. 723)

**chemical formula:** chemical shorthand that uses symbols to tell what elements are in a compound and their ratios. (p. 689)

**chemical potential energy:** energy stored in chemical bonds. (p. 131)

**chemical property:** any characteristic of a substance, such as flammability, that indicates whether it can undergo a certain chemical change. (p. 563)

**chemical reaction:** process in which one or more substances are changed into new substances. (p. 720)

**onda transportadora:** frecuencia específica que se le asigna a una estación de radio y que la usa para emitir señales. (p. 469)

**catalizador:** sustancia que acelera una reacción química sin cambiar el mismo permanentemente. (p. 740)

tubo de rayos catódicos: tubo vacío sellado que produce uno o más haces de electrones para producir una imagen al chocar con el revestimiento del interior de una pantalla de televisor. (p. 472)

**cementación:** proceso de formación de rocas sedimentarias en el que los minerales se precipitan del agua y rellenan los espacios entre los clastos. (p. 625)

**aceleración centrípeta:** aceleración de un objeto dirigida hacia el centro de un trayecto curvo o circular. (p. 110)

**fuerza centrípeta:** fuerza neta dirigida hacia el centro de un trayecto curvo o circular. (p. 110)

**reacción en cadena:** serie continua de reacciones de fisión. (p. 802)

**carga por contacto:** proceso de transferir carga entre objetos por contacto o frotación. (p. 395)

**carga por inducción:** proceso de redistribución de los electrones en un objeto neutro acercándoles un objeto con carga. (p. 396)

**enlace químico:** fuerza que mantiene a los átomos juntos dentro de un compuesto. (p. 694)

**cambio químico:** transformación de una sustancia en una nueva sustancia. (p. 564)

**ecuación química:** método simplificado para describir reacciones químicas usando fórmulas químicas y otros símbolos. (p. 723)

**fórmula química:** nomenclatura química que usa símbolos para expresar qué elementos están en un compuesto y en qué proporción. (p. 689)

**energía química potencial:** energía almacenada en los enlaces químicos. (p. 131)

propiedad química: cualquier característica de una sustancia, como por ejemplo la combustibilidad, que indique si puede someterse a determinado cambio químico. (p. 563)

**reacción química:** proceso en el cual una o más sustancias son cambiadas por nuevas sustancias. (p. 720)

#### cinder cone volcano/concave mirror

- **cinder cone volcano:** small, violently erupting volcano formed by accumulation of large pyroclastic materials around a vent. (p. 377)
- **circuit:** closed conducting loop through which an electric current can flow. (p. 401)
- **clasts:** bits and pieces of rock that vary widely in size and composition, are broken down by weathering, and may become consolidated into sedimentary rock. (p. 624)
- **cleavage:** physical property of a mineral that causes it to break along planes that cut across relatively weak chemical bonds, creating a well-defined, smooth, flat surface. (p. 610)
- **cloud chamber:** radiation detector that uses water or ethanol vapor to detect the paths of charged particles. (p. 796)
- **colloid (KAHL oyd):** heterogeneous mixture whose particles never settle. (p. 556)
- **combustion reaction:** a type of chemical reaction that occurs when a substance reacts with oxygen to produce energy in the form of heat and light. (p. 730)
- **comet:** mass of dust, rock particles, frozen water, methane, and ammonia that travels through space and develops a bright, distinctive tail of light as it approaches the Sun and is pushed on by the solar wind. (p. 236)
- **composite volcano:** large volcano formed by alternating lava flows and violently erupting pyroclastic materials. (p. 378)
- **compound:** substance formed from two or more elements in which the exact combination and proportion of elements is always the same. (p. 554)
- **compound machine:** machine that is a combination of two or more simple machines. (p. 174)
- **compressional wave:** a wave for which the matter in the medium moves back and forth along the direction that the wave travels. (p. 290)
- **computer simulation:** performance-testing method using a computer to imitate the process or procedure or to gather data. (p. 55)
- concave lens: a lens that is thicker at the edges than in the middle; causes light rays to diverge and forms reduced, upright, virtual images; usually used in combination with other lenses. (p. 335)
- **concave mirror:** a reflective surface that curves inward and can magnify objects or create beams of light. (p. 332)

#### volcán de cono de ceniza/espejo cóncavo

- volcán de cono de ceniza: volcán pequeño, de erupción violenta formado por la acumulación de materiales piroclásticos grandes alrededor de una chimenea. (p. 377)
- **circuito:** circuito conductor cerrado a través del cual puede fluir una corriente eléctrica. (p. 401)
- **clastos:** toda clase de objetos rocosos que varían ampliamente en tamaño y composición, son degradados por el clima y pueden consolidarse en rocas sedimentarias. (p. 624)
- **clivaje:** propiedad física de un mineral que causa que éste se rompa en planos que toman el camino más corto entre los enlaces químicos relativamente débiles, creando una superficie bien definida, suave y plana. (p. 610)
- **cámara de vapor:** detector de radiaciones que usa vapor de agua o de etanol para detectar la trayectoria de las partículas cargadas. (p. 796)
- **coloide:** mezcla heterogénea cuyas partículas nunca se sedimentan. (p. 556)
- reacción de combustión: un tipo de reacción química que ocurre cuando una sustancia reacciona con oxígeno para producir energía en forma de calor y luz. (p. 730)
- **cometa:** masa de polvo, partículas de roca, agua congelada, metano y amoniaco que viaja a través del espacio; desarrolla una cauda de luz brillante y distintiva a medida que se acerca al sol, y es empujada por vientos solares. (p. 236)
- **volcán compuesto:** volcán grande formado por flujos alternantes de lava y materiales piroclásticos erupcionados violentamente. (p. 378)
- **compuesto:** sustancia formada por dos o más elementos en la que la combinación y proporción exacta de los elementos es siempre la misma. (p. 554)
- máquina compuesta: máquina compuesta por dos o más máquinas simples. (p. 174)
- onda de compresión: onda para la cual la materia en el medio se mueve hacia adelante y hacia atrás en la dirección en que viaja la onda. (p. 290)
- **simulación computarizada:** método de prueba del desempeño utilizando una computadora para imitar el proceso o procedimiento o para recopilar datos. (p. 55)
- **lente cóncavo:** lente que es más delgado en los bordes que en el centro; hace que los rayos de luz se desvíen y forma imágenes reducidas, verticales y virtuales, generalmente utiliza en combinación con otros lentes. (p. 335)
- **espejo cóncavo:** superficie reflexiva que se curva hacia el interior y que puede amplificar los objetos o crear rayos de luz. (p. 332)

#### concentration/critical mass concentración/masa crítica

- **concentration:** how much solute is present in a solution compared to the amount of solvent. (p. 706)
- **conduction:** transfer of thermal energy by collisions between particles in matter at a higher temperature and particles in matter at a lower temperature. (p. 266)
- **conductor:** material, such as copper wire, in which electrons can move easily. (p. 395)
- **constant:** in an experiment, a variable that does not change when other variables change. (p. 9)
- **constellation:** star pattern that appears to form images, is used by astronomers to locate and name stars, and often is named for a mythological figure. (p. 818)
- **constraints:** design limitations placed on products by outside factors, such as available materials, cost, and environmental impact. (p. 55)
- **continental climate:** a climate that is not directly affected by an ocean. (p. 532)
- **control:** standard used for comparison of test results in an experiment. (p. 9)
- **control system:** device or collection of devices used to monitor a system and limit system failures. (p. 56)
- **convection:** transfer of thermal energy in a fluid from one place to another. (p. 267)
- **convergent boundary:** plate tectonic boundary where lithospheric plates collide. (p. 539)
- **convex lens:** a lens that is thicker in the middle than at the edges and can form real or virtual images. (p. 333)
- **convex mirror:** a reflective surface that curves outward and forms a reduced, upright, virtual image. (p. 333)
- **cosmology:** study of how the universe began, what it is made of, and how it continues to evolve. (p. 836)
- **covalent bond:** attraction formed between atoms when they share electrons. (p. 697)
- **crest:** the highest points on a transverse wave. (p. 294)
- **critical mass:** amount of fissionable material required so that each fission reaction produces approximately one more fission reaction. (p. 802)

- **concentración:** cantidad de soluto que está presente en una solución en comparación con la cantidad de solvente. (p. 706)
- **conducción:** transferencia de energía térmica por colisiones entre partículas de materia a una temperatura alta y partículas de materia a una temperatura más baja. (p. 266)
- **conductor:** material, como el alambre de cobre, a través del cual los electrones se pueden mover con facilidad. (p. 395)
- **constante:** en un experimento, una variable que no cambia cuando cambian otras variables. (p. 9)
- constelación: patrón estelar que parece formar imágenes; es usado por los astrónomos para ubicar y nombrar las estrellas, y con frecuencia se denomina con base en una figura mitológica (p. 818)
- **restricciones:** limitaciones de diseño impuestas en los productos por factores externos, como los materiales disponibles, el costo y el impacto ambiental. (p. 55)
- **clima continental:** un clima que no es afectado directamente por un océano. (p. 532)
- **control:** estándar usado para la comparación de resultados de pruebas en un experimento. (p. 9)
- **sistema de control:** dispositivo o conjunto de dispositivos utilizados para monitorear un sistema y limitar sus fallas. (p. 56)
- **convección:** transferencia de energía térmica en un fluido de un lugar a otro. (p. 267)
- **límite convergente:** límite de la placa tectónica donde las placas litosféricas colisionan. (p. 539)
- **lente convexo:** lente que es más delgado en el centro que en los bordes y que puede formar imágenes reales o virtuales. (p. 333)
- **espejo convexo:** una superficie reflexiva que se curva hacia el exterior y forma una imagen reducida, vertical y virtual. (p. 333)
- **cosmología:** estudio del origen del universo, de su composición y de la forma como continúa evolucionando. (p. 836)
- **enlace covalente:** atracción formada entre átomos que comparten electrones. (p. 697)
- **cresta:** los puntos más altos en una onda transversal. (p. 294)
- masa crítica: cantidad de material fisionable requerido de manera que cada reacción de fisión produzca aproximadamente una reacción de fisión adicional. (p. 802)

dark energy/Earth energía oscura/tierra



- **dark energy:** energy that might be causing accelerated expansion of the universe. (p. 837)
- dark matter: a type of matter that cannot be seen and can only be detected by its gravitational effects. (p. 838)
- **decibel:** unit for sound intensity; abbreviated dB. (p. 322)
- **decomposition reaction:** chemical reaction in which one substance breaks down into two or more substances. (p. 731)
- density: mass per unit volume of a material. (p. 19)
- **dependent variable:** factor that changes as a result of changes in the other variables. (p. 9)
- **deposition:** process in which eroded materials are dropped by their transporting agents. (p. 654)
- **diffraction:** the bending of waves around an obstacle; can also occur when waves pass through a narrow opening. (p. 304)
- **direct current (DC):** electric current that flows in only one direction. (p. 442)
- **discontinuity:** boundary marking an abrupt density change between Earth's layers. (p. 371)
- **displacement:** distance and direction of an object's change in position from the starting point. (p. 71)
- **distance:** how far an object moves. (p. 71)
- **distillation:** process that can separate two substances in a mixture by evaporating a liquid and recondensing its vapor. (p. 563)
- **divergent boundary:** plate tectonic boundary where lithospheric plates are moving apart. (p. 358)
- **Doppler effect:** change in pitch or frequency that occurs when a source of a sound is moving relative to a listener. (p. 330)
- **double-displacement reaction:** chemical reaction that produces a precipitate, water, or a gas when two ionic compounds in solution are combined. (p. 732)
- **drainage basin:** land area that gathers water for a major river. (p. 655)

- **energía oscura:** energía que podría estar causando la expansión acelerada del universo. (p. 837)
- **materia oscura:** un tipo de materia que no se puede considerar y se puede detectar solamente por sus efectos gravitacionales. (p. 838)
- **decibel:** unidad que mide la intensidad del sonido; se abrevia dB. (p. 322)
- **reacción de descomposición:** reacción química en la cual una sustancia se descompone en dos o más sustancias. (p. 731)
- **densidad:** masa por unidad de volumen de un material. (p. 19)
- variable dependiente: factor que varía como resultado de los cambios en las otras variables. (p. 9)
- **deposición:** proceso en el que los materiales erosionados son decantados a partir de sus agentes transportadores. (p. 654)
- **difracción:** curvatura de las ondas alrededor de un obstáculo, la cual también puede ocurrir cuando éstas pasan a través de una abertura angosta. (p. 304)
- **corriente directa (CD):** corriente eléctrica que fluye en una sola dirección. (p. 442)
- **discontinuidad:** límite que marca un cambio abrupto de densidad entre las capas de la Tierra. (p. 371)
- **desplazamiento:** distancia y dirección del cambio de posición de un objeto desde el punto inicial. (p. 71)
- distancia: qué tan lejos se mueve un objeto. (p. 71)
- **destilación:** proceso que puede separar dos sustancias de una mezcla por medio de la evaporación de un líquido y la recondensación de su vapor. (p. 563)
- **límite divergente:** límite de las placas tectónicas donde las placas litosféricas se alejan. (p. 358)
- **efecto Doppler:** cambio en la altura o frecuencia que ocurre cuando una fuente de sonido se mueve en relación con un oyente. (p. 330)
- **reacción de doble desplazamiento:** reacción química que produce un precipitado, agua o gas cuando se combinan dos compuestos iónicos en una solución. (p. 732)
- **cuenca de drenaje:** área terrestre que capta agua para un río grande. (p. 655)

Ε

- Earth: third planet from the Sun; the only planet known to support life and to have water on its surface as a gas, a liquid, and a solid. (p. 225)
- **tierra:** tercer planeta más cercano al ; el único planeta que se sabe que alberga vida y que tiene agua en su superficie en estado sólido, líquido y gaseoso. (p. 225)

ecliptic/El Niño eclíptico/El Niño

- **ecliptic:** yearly path of Earth around the Sun; also, the Sun's apparent path through the zodiac. (p. 192)
- **efficiency:** ratio of the output work done by the machine to the input work done on the machine, expressed as a percentage. (p. 164)
- **elastic potential energy:** energy stored when an object is compressed or stretched. (p. 131)
- **elastic rebound:** sudden energy release that accompanies fault movement and causes earthquakes, or seismic vibrations. (p. 363)
- **electric current:** the net movement of electric charges in a single direction, measured in amperes (A). (p. 400)
- **electric motor:** device that converts electrical energy to mechanical energy by using the magnetic forces between an electromagnet and a permanent magnet to make a shaft rotate. (p. 435)
- **electric power:** rate at which electrical energy is converted to another form of energy; expressed in watts (W). (p. 410)
- **electromagnet:** temporary magnet made by wrapping a wire coil, carrying a current, around an iron core. (p. 432)
- **electromagnetic induction:** process in which electric current is produced in a wire loop by a changing magnetic field. (p. 438)
- **electromagnetic waves:** waves created by vibrating electric charges, can travel through a vacuum or through matter, and have a wide variety of frequencies and wavelengths. (p. 456)
- **electron cloud:** area around the nucleus of an atom where the atom's electrons are most likely to be found. (p. 583)
- **electron dot diagram:** uses the symbol for an element and dots representing the number of electrons in the element's outer energy level. (p. 594)
- **electrons:** particles surrounding the center of an atom that have a charge of 1-.(p. 579)
- **element:** substance with atoms that are all alike. (p. 552)
- **ellipse:** elongated, closed curve with two foci; shape of Earth's orbit around the Sun. (p. 188)
- **El Niño:** a warming of the Pacific Ocean every three to five years, which dramatically alters worldwide weather patterns, and occurs when prevailing trade winds weaken near the equator. (p. 539)

- **eclíptico:** trayectoria anual de la tierra alrededor del Sol; también, la trayectoria aparente del Sol a través del zodíaco. (p. 192)
- **eficiencia:** relación del trabajo efectuado por una máquina y el trabajo hecho en ésta, expresada en porcentaje. (p. 164)
- **energía elástica potencial:** energía almacenada cuando un objeto es comprimido o estirado. (p. 131)
- rebote elástico: liberación súbita de energía que acompaña al movimiento de las fallas y que causa terremotos o vibraciones sísmicas. (p. 363)
- **corriente eléctrica:** movimiento neto de cargas eléctricas en una sola dirección, medido en amperios (A). (p. 400)
- **motor eléctrico:** dispositivo que convierte la energía eléctrica en energía mecánica usando las fuerzas magnéticas entre un electroimán y un imán permanente para que el eje gire. (p. 435)
- potencia eléctrica: proporción a la cual la energía eléctrica se convierte en otra forma de energía; se expresa en vatios (V). (p. 410)
- **electroimán:** imán temporal que se hace envolviendo una bobina de cable que conduce una corriente, alrededor de un núcleo de hierro. (p. 432)
- inducción electromagnética: proceso en el cual una corriente eléctrica es producida en un circuito cerrado de cable mediante un campo magnético cambiante. (p. 438)
- ondas electromagnéticas: ondas creadas por la vibración de cargas eléctricas, que pueden viajar a través del vacío o de la materia y que tienen una amplia variedad de frecuencias y de longitudes de onda. (p. 456)
- nube de electrones: área alrededor del núcleo de un átomo en donde hay más probabilidad de encontrar los electrones de los átomos. (p. 583)
- diagrama de punto de electrones: usa el símbolo de un elemento y puntos que representan el número de electrones en el nivel de energía externo del elemento. (p. 594)
- **electrones:** partículas que rodean el centro de un átomo que tienen la carga de 1—. (p. 579)
- **elemento:** sustancia en la cual todos los átomos son iguales. (p. 552)
- **elipse:** curva alargada y cerrada con dos distancias focales; forma de la órbita terrestre alrededor del Sol. (p. 188)
- El Niño: calentamiento del Océano Pacífico cada tres a cinco años, el cual altera dramáticamente los patrones climáticos en todo del mundo y que ocurre cuando los vientos alisios se debilitan cerca del ecuador. (p. 539)

endothermic reaction/foliated

reacción endotérmica/foliado

- **endothermic reaction:** chemical reaction that requires heat energy in order to proceed. (p. 735)
- **energy:** the ability to do work and cause a change to occur. (p. 128)
- **engineer:** researcher who uses scientific information or ideas to solve problems or human needs and bring technology to consumers. (p. 53)
- **entropy:** a measure of how spread out, or dispersed energy is. (p. 276)
- **epicenter:** point on Earth's surface directly above an earthquake's focus. (p. 364)
- **equinox:** occurs twice a year in March and September when Earth's rotation axis is perpendicular to a line connecting the center of Earth to the center of the Sun. (p. 195)
- **erosion:** removal of surface material through weathering by agents such as wind and water. (p. 654)
- **exothermic reaction:** chemical reaction in which energy is primarily given off in the form of heat. (p. 738)
- **experiment:** organized procedure for testing a hypothesis; tests the effect of one thing on another under controlled conditions. (p. 8)
- **extrasolar planet:** planet in orbit around another star. (p. 222)
- extraterrestrial life: life on other worlds. (p. 239)
- **extrusive igneous rock:** rock formed from rapidly cooling lava that has erupted at Earth's surface or formed from consolidated solid materials expelled from volcanoes. (p. 620)

- **reacción endotérmica:** reacción química que requiere energía de calor para proceder. (p. 735)
- **energía:** capacidad de realizar un trabajo y hacer que ocurra un cambio. (p. 128)
- **ingeniero:** investigador que utiliza información científica o ideas para solucionar problemas o necesidades humanas y brindar tecnología a los consumidores. (p. 53)
- **entropía:** una medida del grado de diseminación o dispersión de la energía. (p. 276)
- **epicentro:** punto de la superficie terrestre directamente encima del foco de un terremoto. (p. 364)
- **equinoccio:** ocurre dos veces un año en marcha y septiembre en que el eje de rotación de la tierra es perpendicular a una línea que conecta el centro de la tierra con el centro del sol. (p. 195)
- **erosión:** remoción del material superficial a través del desgaste por agentes como el viento y el agua. (p. 654)
- **reacción exotérmica:** reacción química en la cual la energía es inicialmente emitida en forma de calor. (p. 738)
- **experimento:** procedimiento organizado para probar una hipótesis; prueba el efecto de una cosa sobre otra bajo condiciones controladas. (p. 8)
- **planeta extrasolar:** planeta en órbita alrededor de otra estrella. (p. 222)
- vida extraterrestre: vida en otros mundos. (p. 239)
- **roca ígnea extrusiva:** roca formada a partir de lava que fue erupcionada a la superficie terrestre y que se enfrió rápidamente o formada a partir de materiales sólidos consolidados expulsados de los volcanes. (p. 620)

F

- **fault:** crack in Earth's crust along which movement has taken place. (p. 364)
- **first law of motion:** states that if the net force on an object is zero, then an object at rest remains at rest, or, if the object is moving, it continues moving with constant velocity. (p. 98)
- **first law of thermodynamics:** states that the increase in thermal energy of a system equals the work done on the system plus the heat added to the system. (p. 274)
- focus: point of origin of an earthquake. (p. 363)
- **foliated:** type of metamorphic rock whose grains are arranged in layers or bands. (p. 631)

- **falla:** fisura en la corteza terrestre a lo largo de la cual ha tenido lugar un movimiento. (p. 364)
- primera ley del movimiento: ley que establece que si la fuerza neta sobre un objeto es cero, entonces un objeto en reposo permanece en reposo, o, si el objeto está moviéndose, éste continúa moviéndose con una velocidad constante. (p. 98)
- primera ley de la termodinámica: establece que el aumento en la energía térmica de un sistema es igual al trabajo realizado sobre el sistema más el calor agregado a éste. (p. 274)
- **foco:** punto de origen de un terremoto. (p. 363)
- **foliado:** tipo de roca metamórfica cuyos granos están dispuestos en capas o bandas. (p. 631)

#### force/Global Positioning System (GPS)

**force:** a push or pull exerted on an object. (p. 81)

**fossil fuels:** oil, natural gas, and coal; formed from the decayed remains of ancient plants and animals. (p. 487)

**fossils:** remains or traces of organisms found in the geologic rock record; can be direct remains such as bones, mold and cast formations, and trace impressions. (p. 671)

**fracture:** physical property of a mineral that causes it to break into uneven pieces. (p. 610)

**frequency:** the number of wavelengths that pass a fixed point each second; expressed in hertz (Hz). (p. 295)

**friction:** a force that opposes the sliding motion between objects that are in contact. (p. 83)

#### fuerza/Sistema de Posicionamiento Global (GPS)

**fuerza:** impulso o tracción sobre un objeto. (p. 81) **combustibles fósiles:** petróleo, gas natural y carbón formados por los restos descompuestos de plantas y animales ancestrales. (p. 487)

**fósiles:** restos o vestigios de organismos que se encuentran en el registro geológico; pueden ser restos directos como huesos, moldes, impresiones fosilizadas e impresiones de huellas. (p. 671)

**fractura:** propiedad física de un mineral que causa que éste se rompa en piezas asimétricas. (p. 610)

**frecuencia:** el número de longitudes de onda que pasan por un punto fijo en un segundo; expresa en hertz (Hz). (p. 295)

**fricción:** una fuerza que se opone al movimiento deslizante entre los objectos que están el contacto. (p. 83)



**galaxy:** large group of stars, gas, and dust held together by gravity; most commonly can be elliptical, spiral, and irregular. (p. 831)

**galvanometer:** a device that uses an electromagnet to measure electric current. (p. 434)

gamma ray: electromagnetic wave with no mass and no charge that travels at the speed of light and is usually emitted with alpha or beta particles from a decaying atomic nucleus; has a wavelength less than about ten trillionths of a meter. (pp. 467, 793)

**Geiger counter:** radiation detector that produces a click or a flash of light when a charged particle is detected. (p. 798)

**generator:** device that uses electromagnetic induction to convert mechanical energy to electrical energy. (p. 400)

**geocentric model:** Earth-centered model of the solar system. (p. 218)

**geothermal energy:** thermal energy in hot magma; can be converted by a power plant into electrical energy. (p. 505)

**giant:** late stage in a star's life cycle that occurs when its hydrogen fuel is depleted, its core contracts, and its outer layers expand and cool. (p. 825)

**Global Positioning System (GPS):** a system of satellites and ground monitoring stations that enable a receiver to determine its location at or above Earth's surface. (p. 475)

**galaxia:** grupo grande de estrellas, gas y polvo mantenidos juntos por la gravedad; comúnmente pueden ser elípticas, espirales e irregulares. (p. 831)

**galvanómetro:** dispositivo que usa un electroimán para medir la corriente eléctrica. (p. 434)

rayo gama: onda electromagnética sin masa ni carga que viaja a la velocidad de la luz y que usualmente es emitida con partículas alfa o beta a partir de un núcleo atómico en descomposición; tiene una electromagnética con longitudes de onda menores a diez trillonésimas de metro. (pp. 467, 793)

**contador Geiger:** detector de radiación que produce un sonido seco o un destello de luz al detectar una partícula cargada. (p. 798)

**generador:** dispositivo que usa inducción electromagnética para convertir energía mecánica en energía eléctrica. (p. 400)

**modelo geocéntrico:** modelo del sistema solar centrado en la tierra. (p. 218)

**energía geotérmica:** energía térmica en el magma caliente, la cual se puede convertir mediante una planta industrial en energía eléctrica. (p. 505)

**gigante:** última etapa en el ciclo de vida de una estrella que ocurre cuando su combustible hidrógeno es agotado, su núcleo se contrae y sus capas externas se expanden y enfrían. (p. 825)

**Sistema de Posicionamiento Global (GPS):** sistema de satélites y estaciones de monitoreo en tierra que permiten que un receptor determine su ubicación en o sobre la superficie terrestre. (p. 475)

#### global warming/hypothesis

calentamiento global/hipótesis

- **global warming:** an increase in the average global temperature. (p. 538)
- **graph:** visual display of information or data that can provide a quick way to communicate a lot of information and allow scientists to observe patterns. (p. 22)
- **gravitational potential energy:** energy stored by objects due to their position above Earth's surface; depends on the distance above Earth's surface and the object's mass. (p. 132)
- **gravity:** attractive force between two objects that depends on the masses of the objects and the distance between them. (p. 104)
- **greenhouse effect:** atmospheric warming caused by the emission of infrared waves by gases in Earth's atmosphere. (p. 520)
- **group:** vertical column in the periodic table. (p. 592)

- **calentamiento global:** un aumento en la temperatura global media. (p. 538)
- **gráfica:** presentación visual de información que puede suministrar una forma rápida de comunicar gran cantidad de información y que permite que los científicos puedan observar los patrones. (p. 22)
- **energía gravitacional potencial:** energía almacenada por objetos debido a su posición sobre la superficie terrestre, la cual depende de la distancia sobre la superficie terrestre y de la masa del objeto. (p. 132)
- **gravedad:** fuerza de atracción entre dos objetos que depende de las masas de los objetos y de la distancia entre ellos. (p. 104)
- **efecto de invernadero:** el calentarse atmosférico causado por la emisión de las ondas infrarrojas por los gases en la atmósfera de la tierra. (p. 520)
- **grupo:** columna vertical en la tabla periódica. (p. 592)

H

- half-life: amount of time it takes for half the nuclei in a sample of a radioactive isotope to decay. (p. 794)
- **hardness:** physical property of a mineral that measures resistance to scratching. (p. 611)
- **heat:** thermal energy that flows from a warmer material to a cooler material. (p. 257)
- **heat of fusion:** amount of energy required to change a substance from the solid phase to the liquid phase. (p. 262)
- **heat of vaporization:** the amount of energy required for the liquid at its boiling point to become a gas. (p. 262)
- **heliocentric model:** Sun-centered model of the solar system. (p. 219)
- heterogeneous (het uh ruh JEE nee us) mixture: mixture, such as mixed nuts or a dry soup mix, in which different materials are unevenly distributed and are easily identified. (p. 555)
- homogeneous (hoh moh JEE nee us) mixture: solid, liquid, or gas that contains two or more substances blended evenly throughout. (p. 556)
- hydrate: compound that has water chemically attached to its ions and written into its chemical formula. (p. 708)
- **hydroelectricity:** electricity produced from the energy of falling water. (p. 503)
- **hypothesis:** a possible solution or an explanation that is consistent with what is known. (p. 8)

- vida media: tiempo requerido para que se descomponga la mitad de los núcleos de una muestra de isótopo radiactivo. (p. 794)
- **dureza:** propiedad física de un mineral que mide la resistencia al desgaste. (p. 611)
- **calor:** energía térmica que fluye de un material caliente a uno frío. (p. 257)
- **calor de fusión:** cantidad de energía necesaria para cambiar una sustancia del estado sólido al líquido. (p. 262)
- **calor de vaporización:** cantidad de energía necesaria para que un líquido en su punto de ebullición se convierta en gas. (p. 262)
- **modelo heliocéntrico:** modelo del sistema solar centrado en el sol. (p. 219)
- mezcla heterogénea: mezcla, tal como una mezcla de nueces o una mezcla seca para hacer sopa, en la cual diferentes materiales están distribuidos en forma desigual y se pueden identificar fácilmente. (p. 555)
- **mezcla homogénea:** sólido, liquido, o gas que contiene dos o más sustancias mezcladas de manera uniforme en toda la mezcla. (p. 556)
- hidrato: compuesto que contiene agua químicamente conectada a sus iones y representada en su fórmula química. (p. 708)
- hidroelectricidad: electricidad producida a partir de la energía generada por una caída de agua. (p. 503)
- **hipótesis:** una solución posible o una explicación que es constante con se sabe qué. (p. 8)

inclined plane/ionic bond

plano inclinado/enlace iónico

Т

inclined plane: simple machine that consists of a sloping surface, such as a ramp, that reduces the amount of force needed to lift something by increasing the distance over which the force is applied. (p. 172)

**independent variable:** factor that, as it changes, affects the measure of another variable. (p. 9)

index of refraction: property of a material indicating how much light slows down when traveling in the material. (p. 329)

**indicator:** organic compound that changes color in acids and bases. (p. 764)

**inertia:** resistance of an object to a change in its motion. (p. 99)

**infiltration:** process by which water enters Earth to become groundwater, controlled by the slope of the land, type of surface material, and type and amount of vegetation. (p. 663)

**infrared waves:** electromagnetic waves that have a wavelength between about 1 mm and 750 billionths of a meter. (p. 464)

**inhibitor:** substance that slows down a chemical reaction or prevents it from occurring by combining with a reactant. (p. 740)

**input force**: force exerted on a machine. (p. 162)

**instantaneous speed:** speed of an object at a given point in time; is constant for an object moving with constant speed, and changes with time for an object that is slowing down or speeding up. (p. 71)

**insulator:** material in which electrons are not able to move easily. (p. 395); material in which heat flows slowly. (p. 270)

**intensity:** amount of energy that flows through a certain area in a specific amount of time. (p. 322)

**interference:** occurs when two or more waves overlap and combine to form a new wave. (p. 306)

**internal combustion engine:** heat engine that burns fuel inside the engine in chambers or cylinders. (p. 275)

intrusive igneous rock: coarse-grained rock formed from slowly cooling magma below Earth's surface. (p. 617)

**ion:** charged particle that has either more or fewer electrons than protons. (pp. 692, 707)

**ionic bond:** attraction formed between oppositely charged ions in an ionic compound. (p. 696)

plano inclinado: máquina simple que consiste de una superficie inclinada, tal como una rampa, que reduce la fuerza necesaria para levantar un objeto aumentando la distancia sobre la cual se aplica dicha fuerza. (p. 172)

variable independiente: factor que, a medida que cambia, afecta la medida de otra variable. (p. 9)

**índice de refracción:** propiedad de un material para indicar la cantidad de luz que se frena al pasar a través del material. (p. 329)

**indicador:** compuesto orgánico que cambia de color en presencia de ácidos y bases. (p. 764)

inercia: resistencia de un objeto a cambiar su movimiento. (p. 99)

infiltración: proceso mediante el cual el agua entra en la tierra para convertirse en agua subterránea, controlado por la pendiente del suelo, el tipo de material superficial y el tipo y cantidad de vegetación. (p. 663)

ondas infrarrojas: ondas electromagnéticas que tienen una longitud de onda entre aproximadamente 1 mm y 750 billonésimas de metro. (p. 464)

**inhibidor:** sustancia que reduce una reacción química o previene que ocurra por una combinación con un reactivo. (p. 740)

**fuerza de entrada:** fuerza ejercida sobre una máquina. (p. 162)

velocidad instantánea: velocidad de un objeto en un punto dado en el tiempo; es constante para un objeto que se mueve a una velocidad constante y cambia con el tiempo en un objeto que está reduciendo o aumentando su velocidad. (p. 71)

**aislador:** material a través del cual los electrones no se pueden mover con facilidad. (p. 395); material en el cual el calor fluye lentamente. (p. 270)

**intensidad:** cantidad de energía que fluye a través de cierta área en un tiempo específico. (p. 322)

interferencia: ocurre cuando dos o más ondas se sobreponen y combinan para formar una nueva onda. (p. 306)

motor de combustión interna: motor de calor que quema combustible en su interior en cámaras o cilindros. (p. 275)

**roca ígnea intrusiva:** roca áspera y granulosa formada a partir de un enfriamiento lento del magma debajo de la superficie terrestre. (p. 617)

ion: partícula cargada que tiene ya sea más o menos electrones que protones. (pp. 692, 707)

**enlace iónico:** atracción formada entre iones con cargas opuestas en un compuesto iónico. (p. 696)

#### isotopes/law of conservation of momentum

isótopos/ley de la conservación del movimiento

**isotopes:** atoms of the same element that have different numbers of neutrons. (p. 586)

**isótopos:** átomos del mismo elemento que tienen diferente número de neutrones. (p. 586)

J

**jet stream:** high-speed, powerful air current that affects many weather processes, such as the development of storms. (p. 525)

joule: SI unit of energy. (p. 130)

**Jupiter:** largest and fifth planet from the Sun; has continuous, swirling, high-pressure gas storms, the largest of which is the Great Red Spot. (p. 231)

**corriente a presión:** corriente de aire poderosa y de alta velocidad que afecta a muchos procesos climáticos, como el desarrollo de las tormentas. (p. 525)

julio: unidad SI de energía. (p. 130)

**Júpiter:** quinto planeta más cercano al Sol, también es el más grande; tiene tormentas gaseosas arremolinadas y continuas de alta presión, la más grande de las cuales es la Gran Mancha Roja. (p. 231)

K

**Kelvin:** the SI unit for temperature, abbreviated K; a temperature change of 1 Kelvin is the same as a temperature change of 1°C. (p. 255)

**kinetic energy:** energy a moving object has because of its motion; depends on the mass and speed of the object. (p. 130)

**kinetic theory:** explanation of the behavior of molecules in matter; states that all matter is made of constantly moving particles that collide without losing energy. (p. 254)

**Kelvin:** la unidad del sistema internacional de medidas para la temperatura, cuya abreviatura es K; un cambio en la temperatura de 1 grado kelvin es lo mismo que un cambio en la temperatura de 1°C. (p. 255)

**energía cinética:** energía que tiene un cuerpo debido a su movimiento, la cual depende de la masa y velocidad del objeto. (p. 130)

**teoría cinética:** explicación del comportamiento de las moléculas en la materia, la cual establece que todas las sustancias están compuestas de partículas en constante movimiento que colindan sin perder energía. (p. 254)

ī

**La Niña:** climatic phenomenon that occurs when Pacific trade winds are very strong and temperatures colder than normal; the opposite of El Niño. (p. 539)

**latent heat:** thermal energy released when water freezes or condenses. (p. 520)

**law of conservation of charge:** states that charge can be transferred from one object to another but cannot be created or destroyed. (p. 393)

**law of conservation of energy:** states that energy can never be created or destroyed. (p. 139)

**law of conservation of mass:** states that the mass of all substances present before a chemical change equals the mass of all the substances remaining after the change. (p. 567)

**law of conservation of momentum:** states that if a group of objects exerts forces only on each other, then the total momentum of the objects doesn't change (p. 117)

La Niña: fenómeno climático que ocurre cuando los vientos alisios del pacífico son muy fuertes y la temperatura disminuye más de lo normal; lo opuesto a El Niño. (p. 539)

**calor latente:** la energía termal lanzó cuando el agua congela o condensa. (p. 520)

**ley de la conservación de carga:** establece que la carga puede ser transferida entre un objeto y otro pero no puede ser creada o destruida. (p. 393)

**ley de la conservación de energía:** establece que la energía nunca puede ser creada ni destruida. (p. 139)

**ley de conservación de la masa:** establece que la masa de todas las sustancias presente antes de un cambio químico es igual a la masa de todas las sustancias resultantes después del cambio. (p. 567)

**ley de la conservación del movimiento:** ley que establece que si en un grupo de objetos se ejercen fuerzas sólo en unos sobre otros, entonces el momento total de los objetos no cambia. (p. 117)

#### lee rain shadow/maritime climate

sombra lluviosa a sotavento/clima marítimo

- **lee rain shadow:** area of reduced precipitation on one side of a mountain range. (p. 533)
- **lever:** simple machine consisting of a bar free to pivot about a fixed point called the fulcrum. (p. 166)
- **light-year:** distance light travels in one year—about 9.5 trillion km. (p. 820)
- **Local Group:** cluster of about 50 galaxies, including the Milky Way. (p. 831)
- **longshore current:** movement of water parallel to the shoreline caused by waves colliding with the shore at an angle, which results in net sediment transport parallel to the shoreline. (p. 659)
- **loudness:** human perception of sound intensity. (p. 322)
- **lunar eclipse:** occurs during full moon, when the Moon enters Earth's umbra and Earth casts a curved shadow on the Moon's surface. (p. 202)

- **sombra lluviosa a sotavento:** área de precipitación reducida en un lado de un sistema montañoso. (p. 533)
- palanca: máquina simple que consiste de una barra que puede girar sobre un punto fijo llamado pivote. (p. 166)
- **año luz:** distancia que viaja la luz en un año—cerca de 9 500 trillones de km. (p. 820)
- **Grupo Local:** agrupación de cerca de 50 galaxias, incluyendo la Vía Láctea. (p. 831)
- corriente costera: movimiento de agua paralelo a la línea costera causado por olas que colisionan con la costa en ángulo, lo cual resulta en transporte neto de sedimentos paralelo a la línea costera. (p. 659)
- **volumen de sonido:** percepción humana de la intensidad del sonido. (p. 322)
- eclipse lunar: fenómeno que ocurre durante la luna llena, cuando la Luna entra en el cono de sombra de la Tierra y ésta proyecta una sombra curva sobre la superficie de la Luna. (p. 202)

M

- machine: device that makes doing work. easier by increasing the force applied to an object, changing the direction of an applied force, or increasing the distance over which a force can be applied. (p. 160)
- **magma:** molten rock material found inside Earth. (p. 613)
- magnetic domain: group of atoms in a magnetic material with the magnetic poles of the atoms pointing in the same direction. (p. 429)
- magnetic field: surrounds a magnet and exerts a force on other magnets and objects made of magnetic materials. (p. 425)
- magnetic pole: region on a magnet where the magnetic force exerted by a magnet is strongest; like poles repel and opposite poles attract. (p. 425)
- **magnetism:** the properties and interactions of magnets. (p. 424)
- main sequence: section of an H-R diagram that is plotted from the upper left to the lower right and contains 90 percent of all known stars. (p. 823)
- maria: relatively flat, dark-colored regions on the Moon's surface. (p. 203)
- maritime climate: climate with a strong ocean influence and milder temperatures. (p. 532)

- **máquina:** artefacto que facilita la ejecución del trabajo aumentando la fuerza que se aplica a un objeto, cambiando la dirección de una fuerza aplicada o aumentando la distancia sobre la cual se puede aplicar una fuerza. (p. 160)
- **magma:** material rocoso derretido que se encuentra en el interior de la Tierra. (p. 613)
- **dominio magnético:** grupo de átomos en un material magnético en el cual los polos magnéticos de los átomos apuntan en la misma dirección. (p. 429)
- **campo magnético:** rodea a un imán y ejerce una fuerza sobre otros imanes y objetos hechos de materiales magnéticos. (p. 425)
- **polo magnético:** zona en un imán en donde la fuerza magnética ejercida por un imán es la más fuerte; los polos iguales se repelen y los polos opuestos se atraen. (p. 425)
- **magnetismo:** propiedades e interacciones de los imanes. (p. 424)
- **secuencia principal:** sección de un diagrama H-R que es graficado desde la parte superior izquierda hasta la parte inferior derecha y contiene el 90% de todas las estrellas conocidas. (p. 823)
- maría: egiones relativamente planas y de color oscuro sobre la superficie de la luna. (p. 203)
- **clima marítimo:** clima con una fuerte influencia oceánica y temperaturas templadas. (p. 532)

Mars/moon phase marte/fase lunar

Mars: fourth planet from the Sun; called the red planet because of high concentrations of iron oxide. (p. 225)

mass: amount of matter in an object. (p. 19) mass number: sum of the number of protons and neutrons in an atom's nucleus. (p. 585)

mechanical advantage (MA): ratio of the output force exerted by a machine to the input force applied to the machine. (p. 164)

**mechanical energy:** sum of the potential energy and kinetic energy in a system. (p. 136)

medium: matter in which a wave travels. (p. 289)

**Mercury:** closest planet to the Sun; has a larger than expected iron core. (p. 223)

**meteoroid:** rocky solar system object formed from pieces of comets and asteroids. (pp. 236, 633)

**microwaves:** radio waves with wavelengths of between about 1 m and 1 mm. (p. 463)

mid-ocean ridge (MOR): a system of twin mountain ranges with a rift valley between them that extends around Earth on the seafloor; formed where two oceanic plates are forced apart due to magma rising from Earth's mantle; a source of new rock. (p. 356)

Milky Way: a spiral galaxy that is about 100,000 lightyears in diameter and contains from 200 to 400 billion stars, including the Sun. (p. 831)

mineral: naturally occurring, inorganic, crystalline solid with a predictable chemical composition and a characteristic set of physical properties. (p. 609)

**model:** can be used to represent an idea, object, or event that is too big, too small, too complex, or too dangerous to observe or test directly. (p. 11)

**molecule:** a neutral particle that forms as a result of electron sharing. (p. 697)

**momentum:** property of a moving object that equals its mass times its velocity. (p. 116)

moon phase: changing appearance of the Moon as viewed from Earth, depending on the relative positions of the Sun, the Moon, Earth, and the observer. (p. 199)

marte: cuarto planeta más cercano al Sol; llamado el planeta rojo debido a altas concentraciones de óxido de hierro. (p. 225)

masa: cantidad de materia en un objeto. (p. 19)

**número de masa:** suma del número de protones y neutrones en el núcleo de un átomo. (p. 585)

ventaja mecánica (MA): relación de la fuerza ejercida por una máquina y la fuerza aplicada a dicha máquina. (p. 164)

**energía mecánica:** suma de la energía potencial y energía cinética en un sistema. (p. 136)

medio: materia a través de la cual viaja una onda. (p. 289)

**Mercurio:** planeta más cercano al sol; tiene un núcleo de hierro más grande de lo esperado. (p. 223)

**meteorito:** objeto rocoso del sistema solar formado de pedazos de cometas y asteroides. (pp. 236, 633)

microondas: ondas de radio con longitudes de onda entre aproximadamente 1 mm y 1 m. (p. 463)

canto del mediados de-océano (MOR): un sistema de la montaña gemela se extiende con un valle de la grieta entre ellos que extienda alrededor de la tierra en el seafloor; formado donde están dos placas oceánicas separado forzado debido al magma que se levanta de la capa de la tierra; una fuente de la roca nueva. (p. 356)

**Vía Láctea:** una galaxia espiral que es cerca de 100.000 años luz de diámetro y contiene a partir 200 000 a 400 000 millones de estrellas, incluyendo el sol. (p. 831)

mineral: sólido de origen natural, inorgánico y cristalino con una composición química predecible y un conjunto característico de propiedades físicas. (p. 609)

**modelo:** puede ser usado para representar una idea, objeto o evento que es demasiado grande, demasiado pequeño, demasiado complejo o demasiado peligroso para ser observado o probado directamente. (p. 11)

**molécula:** partícula neutra que se forma al compartir electrones. (p. 697)

**impetu:** propiedad de un objeto en movimiento que es igual a su masa por su velocidad. (p. 116)

fase lunar: cambio en la apariencia de la Luna según es vista desde la Tierra, dependiendo de las posiciones relativas del Sol, la Luna, la Tierra y el observador. (p. 199)

Neptune/parallel circuit Neptuno/circuito paralelo

N

**Neptune:** eighth planet from the Sun; has storms similar to Jupiter's and appears blue because of atmospheric methane. (p. 235)

**net force:** sum of the forces that are acting on an object. (p. 82)

**neutron:** neutral particle, composed of quarks, inside the nucleus of an atom. (p. 579)

**nonpolar molecule:** molecule that shares electrons equally and does not have oppositely charged ends. (p. 700)

**nonrenewable resources:** natural resource, such as fossil fuels, that cannot be replaced by natural processes as quickly as it is used. (p. 493)

**nuclear fission:** process of splitting an atomic nucleus into two or more nuclei with smaller masses. (p. 801)

**nuclear fusion:** reaction in which two or more atomic nuclei form a nucleus with a larger mass. (p. 803)

**nuclear reactor:** uses energy from a controlled nuclear chain reaction to generate electricity. (p. 494)

**nuclear waste:** radioactive by-product that results when radioactive materials are used. (p. 498)

**nucleus:** positively charged center of an atom that contains protons and neutrons and is surrounded by a cloud of electrons. (p. 579)

**Neptuno:** octavo planeta más cercano al Sol; tiene tormentas similares a las de Júpiter y parece azul debido al metano atmosférico. (p. 235)

**fuerza neta:** suma de fuerzas que actúan sobre un objeto. (p. 82)

**neutrón:** partícula neutra, compuesta por quarks, dentro del núcleo de un átomo. (p. 579)

molécula no polar: molécula que comparte equitativamente los electrones y que no tiene extremos con cargas opuestas. (p. 700)

**recursos no renovables:** recursos naturales, tales como combustibles fósiles, que no pueden ser reemplazados por procesos naturales tan pronto como son usados. (p. 493)

**fisión nuclear:** proceso de división de un núcleo atómico en dos o más núcleos con masas más pequeñas. (p. 801)

**fusión nuclear:** reacción en la cual dos o más núcleos atómicos forman un núcleo con mayor masa. (p. 803)

**reactor nuclear:** usa energía de una reacción nuclear controlada en cadena para generar electricidad. (p. 494)

**desperdicio nuclear:** subproducto radioactivo que resulta del uso de materiales radiactivos. (p. 498)

**núcleo:** centro de un átomo con carga positiva que contiene protones y neutrones y está rodeado por una nube de electrones. (p. 579)

0

**Ohm's law:** states that the current in a circuit equals the voltage difference divided by the resistance. (p. 405)

**opaque:** material that absorbs or reflects all light and does not transmit any light. (p. 327)

**output force:** force applied by a machine. (p. 162)

**oxidation number:** positive or negative number that indicates how many electrons an atom has gained, lost, or shared to become stable. (p. 703)

**ley de Ohm:** establece que la corriente en un circuito es igual a la diferencia de voltaje dividida por la resistencia. (p. 405)

**opaco:** material que absorbe o refleja toda la luz pero no la transmite. (p. 327)

**fuerza de salida:** fuerza aplicada por una máquina. (p. 162)

**número de oxidación:** número positivo o negativo que indica cuántos electrones ha ganado, perdido o compartido un átomo para poder ser estable. (p. 703)

P

**parallel circuit:** circuit in which electric current has more than one path to follow. (p. 406)

**circuito paralelo:** circuito en el cual la corriente eléctrica tiene más de una trayectoria para seguir. (p. 406)

period/polyatomic ion periodo/ion poliatómico

- **period:** the amount of time it takes one wavelength to pass a fixed point; expressed in seconds. (p. 295); horizontal row in the periodic table. (p. 595)
- **periodic table:** organized list of all known elements that are arranged by increasing atomic number and by changes in chemical and physical properties. (p. 588)
- **petroleum:** liquid fossil fuel formed from decayed remains of ancient organisms; can be refined into fuels and used to make plastics. (p. 489)
- **pH:** a measure of the concentration of hydronium ions in a solution using a scale ranging from 0 to 14, with 0 being the most acidic and 14 being the most basic. (p. 773)
- **photon:** particle that electromagnetic waves sometimes behave like; has energy that increases as the frequency of the electromagnetic wave increases. (p. 460)
- photosphere: light-emitting surface of the Sun. (p. 827)photovoltaic cell: device that converts solar energy into electricity; also called a solar cell. (p. 501)
- **physical change:** any change in size, shape, or state of matter in which the identity of the substance remains the same. (p. 562)
- **physical property:** any characteristic of a material, such as size or shape, that you can observe or attempt to observe without changing the identity of the material. (p. 560)
- **pigment:** colored material that is used to change the color of other substances. (p. 342)
- **pilot plant:** scaled-down version of real production equipment that closely models actual manufacturing conditions and is used to test a new manufacturing process. (p. 56)
- **pitch:** how high or low a sound seems; related to the frequency of the sound waves. (p. 323)
- **plane mirror:** flat, smooth mirror that reflects light to form upright, virtual images. (p. 331)
- **plasma:** matter consisting of positively and negatively charged particles. (p. 261)
- **Pluto:** dwarf planet; has a thin atmosphere and a solid, ice-rock surface. (p. 236)
- **polar molecule:** molecule with a slightly positive end and a slightly negative end as a result of electrons being shared unequally. (p. 700)
- **polyatomic ion:** positively or negatively charged, covalently bonded group of atoms. (p. 707)

- período: la cantidad de tiempo que requiere una longitud de onda para pasar un punto fijo; expresa en segundos. (p. 295); fila horizontal en la tabla periódica. (p. 595)
- tabla periódica: lista organizada de todos los elementos conocidos y que han sido ordenados de manera ascendente por número atómico y por cambios en sus propiedades químicas y físicas. (p. 588)
- **petróleo:** combustible fósil líquido que se forma a partir de residuos en descomposición de organismos ancestrales y que puede ser refinado para producir combustibles y usado para hacer plásticos. (p. 489)
- **pH:** medida de la concentración de iones de hidronio en una solución, usando una escala de 0 a 14, en la cual 0 es la más ácida y 14 la más básica. (p. 773)
- fotón: partícula como la cual algunas veces se comportan las ondas electromagnéticas; tiene energía que aumenta a medida que la frecuencia de la onda electromagnética aumenta. (p. 460)
- fotosfera: superficie solar que emite luz. (p. 827)
- **células fotovoltaicas:** dispositivo que convierte la energía solar en electricidad; también llamada celda solar. (p. 501)
- **cambio físico:** cualquier cambio en tamaño, forma o estado de una sustancia en la cual la identidad de la sustancia sigue siendo la misma. (p. 562)
- **propiedad física:** cualquier característica de un material, tal como tamaño o forma, que se puede haber observar o tratado de observar sin cambiar la identidad del material. (p. 560)
- **pigmento:** material de color que se usa para cambiar el color de otras sustancias. (p. 342)
- **planta piloto:** versión a escala reducida de un equipo de producción real que simula cercanamente las condiciones reales de fabricación y es utilizada para probar un proceso de fabricación nuevo. (p. 56)
- **altura:** qué tan alto o bajo parece un sonido; tiene relación con la frecuencia de las ondas sonoras. (p. 323)
- **espejo plano:** espejo plano y liso que refleja la luz para formar imágenes verticales y virtuales. (p. 331)
- **plasma:** materia consistente de partículas con cargas positivas y negativas. (p. 261)
- **Plutón:** planeta enana; tiene una atmósfera delgada y una superficie sólida de hielo y roca. (p. 236)
- **molécula polar:** molécula con un extremo ligeramente positivo y otro ligeramente negativo como resultado de un compartir desigual de los electrones. (p. 700)
- **ion poliatómico:** grupo de átomos enlazados covalentemente, con carga positiva o negativa. (p. 707)

#### pore space/radio waves

### espacio de poro/ondas de radio

- **pore space:** the empty space between clasts or grains in a material. (p. 625)
- **porosity:** the percentage of a material's total volume that is pore space; equal to the volume of all the pore spaces divided by the material's total volume. (p. 665)
- **potential energy:** stored energy an object has due to its position. (p. 131)
- **power:** amount of work done, or the amount of energy transferred, divided by the time required to do the work or transfer the energy; measured in watts (W). (p. 157)
- **precision:** describes how closely measurements are to each other and how carefully the measurements were made. (p. 14)
- **principle of superposition:** states that the oldest rocks in an undisturbed sequence of rocks are at the bottom of the undisturbed sequence. (p. 670)
- **product:** in a chemical reaction, the new substance that is formed. (p. 720)
- **proton:** particle, composed of quarks, inside the nucleus of an atom that has a charge of 1+. (p. 579)
- **prototype:** first full-scale model built to performance-test a new product. (p. 56)
- **pulley:** simple machine that consists of a grooved wheel with a rope, chain, or cable running along the groove; can be either fixed or movable. (p. 169)

- **espacio de poro:** el espacio vacío entre los clasts o los granos en un material. (p. 625)
- **porosidad:** el porcentaje del volumen total de un material que es espacio de poro; el igual al volumen de todos los espacios de poro se dividió por el volumen total del material. (p. 625)
- **energía potencial:** energía almacenada que un objeto tiene debido a su posición. (p. 131)
- potencia: cantidad de trabajo realizado o cantidad de energía transferida, dividida por el tiempo requerido para realizar el trabajo o transferir la energía; medida en vatios (V). (p. 157)
- **precisión:** descripción de la cercanía de las mediciones una respecto a otra y del cuidado con el que se hacen éstas. (p. 14)
- principio de superposición (estratigráfico): principio que establece que las rocas más antiguas en una secuencia de rocas sin perturbaciones están en la parte más baja de la secuencia no perturbada. (p. 670)
- **producto:** es la nueva sustancia que se forma en una reacción química. (p. 720)
- **protón:** partícula, compuesta por quarks, dentro del núcleo de un átomo que tiene una carga de 1+. (p. 579)
- **prototipo:** el primer modelo a escala completa construido para probar el desempeño de un producto nuevo. (p. 56)
- polea: máquina simple que consiste de una rueda acanalada con una cuerda, cadena o cable que se desliza por el canal y que puede ser fija o móvil. (p. 169)



- **quarks:** particles of matter that make up protons and neutrons. (p. 579)
- **quarks:** partículas de materia que constituyen los protones y neutrones. (p. 579)



- **radiant energy:** energy carried by an electromagnetic wave. (p. 459)
- **radiation:** transfer of thermal energy by electromagnetic waves. (p. 269)
- radioactivity: process that occurs when a nucleus decays and emits alpha, beta, or gamma radiation. (p. 788)
- **radio telescope:** telescope that collects and magnifies radio waves. (p. 821)
- **radio waves:** electromagnetic waves with wavelengths longer than about 1 mm, used for communications. (p. 463)

- energía radiante: energía transportada por una onda electromagnética. (p. 459)
- **radiación:** transferencia de energía térmica mediante ondas electromagnéticas. (p. 269)
- **radiactividad:** proceso que ocurre cuando un núcleo se descompone y emite radiación alfa, beta o gama. (p. 788)
- **radio telescopio:** telescopio que colecta y magnifica las ondas de radio. (p. 821)
- ondas de radio: ondas electromagnéticas con longitudes de onda más largas de aproximadamente 1 mm y que se usan en las comunicaciones. (p. 463)

#### rarefaction/saturated solution

rarefacción/solución saturada

- **rarefaction:** the least dense regions of a compressional wave. (p. 294)
- rate of reaction: the speed at which reactants are consumed and products are produced in a given reaction. (p. 738)
- **reactant:** in a chemical reaction, the substance that reacts. (p. 720)
- **reflecting telescope:** optical instrument that uses a concave mirror to collect light and a lens to magnify an image. (p. 820)
- **refracting telescope:** optical instrument that uses double convex lenses to collect light and magnify an image. (p. 819)
- **refraction:** the bending of a wave as it changes speed in moving from one medium to another. (p. 302)
- **regolith:** layer of debris on the Moon's surface formed by the accumulation of meteoric material. (p. 203)
- **relative dating:** process of dating objects or events in time order, or sequence, based on logical relationships; may or may not involve the use of numbers. (p. 669)
- **renewable resource:** energy source that is replaced almost as quickly as it is used. (p. 501)
- **resistance:** tendency for a material to oppose electron flow and change electrical energy into thermal energy and light; measured in ohms  $(\Omega)$ . (p. 403)
- **resonance:** the process by which an object is made to vibrate by absorbing energy at its natural frequencies. (p. 309)
- **revolution:** movement of Earth in its orbit around the Sun; used to measure time in years. (p. 192)
- **rift valley:** long, linear, dropped-down valley between twin, parallel mountain ranges produced by faulting. (p. 356)
- **rock:** consolidated, natural mixture of minerals, volcanic glass, or rock fragments. (p. 617)
- **rock cycle:** continuous process that forms and changes rocks on Earth's surface and deep below the surface. (p. 634)
- **rotation:** spinning of Earth on its axis; used to measure time in days. (p. 192)

- rarefacción: las regiones menos densas de una onda de compresión. (p. 294)
- **fasa de reacción:** velocidad a la que los reactantes son consumidos y los productos son generados en una reacción dada. (p. 738)
- **reactante:** es la sustancia que reacciona en una reacción química. (p. 720)
- **telescopio de reflexión:** instrumento óptico que utiliza un espejo cóncavo para captar la luz y una lente para magnificar una imagen. (p. 820)
- **telescopio de refracción:** instrumento óptico que utiliza lentes convexas dobles para captar la luz y magnificar una imagen. (p. 819)
- **refracción:** curvatura de una onda al cambiar su velocidad al pasar de un medio a otro. (p. 302)
- **regolito:** capa de escombros sobre la superficie lunar formada por la acumulación de material meteórico. (p. 203)
- datación relativa: proceso de datar objetos o eventos en un orden o secuencia temporal, basado en relaciones lógicas; puede o no involucrar el uso de números. (p. 669)
- **recursos renovables:** fuente de energía que es reemplazada casi tan pronto como es usada. (p. 501)
- **resistencia:** tendencia de un material de oponerse al fluido de los electrones y convertir la energía eléctrica en energía térmica y luz; se mide en ohmios  $(\Omega)$ . (p. 403)
- **resonancia:** el proceso por el cual un objeto vibra al absorber energía en sus frecuencias naturales. (p. 309)
- **revolución:** movimiento de la Tierra en su órbita alrededor del sol, utilizado para medir el tiempo en años. (p. 192)
- valle de hendidura: valle alargado, lineal y deprimido producido por una falla que se encuentra entre dos sistemas montañosos paralelos. (p. 356)
- **roca:** mezcla natural y consolidada de minerales, obsidiana o fragmentos de roca. (p. 617)
- ciclo de la roca: proceso continuo que forma y cambia las rocas sobre y debajo de la superficie terrestre. (p. 634)
- **rotación:** giro de la Tierra sobre su eje, utilizado para medir el tiempo en días. (p. 192)

S

- **saturated solution:** any solution that contains all the solute it can hold at a given temperature. (p. 761)
- **solución saturada:** cualquier solución que contiene todo el soluto que puede retener a una temperatura determinada. (p. 761)

Saturn/society Saturno/sociedad

- **Saturn:** second-largest and sixth planet from the Sun; has the most complex system of rings. (p. 234)
- scientific law: statement about what happens in nature that seems to be true all the time; does not explain why or how something happens. (p. 12)
- scientific methods: organized set of investigation procedures that can include stating a problem, forming a hypothesis, researching and gathering information, testing a hypothesis, analyzing data, and drawing conclusions. (p. 7)
- **screw:** simple machine that consists of an inclined plane wrapped in a spiral around a cylindrical post. (p. 173)
- **sea breeze:** cooling breeze that blows from the sea toward land during the afternoon. (p. 533)
- second law of motion: states that the acceleration of an object is in the same direction as the net force on the object, and that the acceleration equals the net force divided by the mass. (p. 102)
- **second law of thermodynamics:** states that is impossible for heat to flow from a cool object to a warmer object unless work is done. (p. 274)
- **sediment transport:** movement of eroded materials by wind, water, and/or glaciers from one location to another. (p. 654)
- **Sedna:** unofficial name for object 2003 VB12, a distant planetoid with a very elliptical orbit. (p. 237)
- **series circuit:** circuit in which electric current has only one path to follow. (p. 407)
- **shadow zone:** "dead zone" between 105 and 140 degrees from an earthquake's epicenter, where nothing is recorded on a seismogram. (p. 371)
- **shield volcano:** broad, flat volcano formed by layers of free-flowing, high-temperature, basaltic lava. (p. 377)
- **simple machine:** machine that does work with only one movement—lever, pulley, wheel and axle, inclined plane, screw, and wedge. (p. 166)
- **single-displacement reaction:** chemical reaction in which one element replaces another element in a compound. (p. 731)
- **sliding friction:** frictional force that opposes the motion of two surfaces sliding past each other. (p. 84)
- **society:** group of people who share similar values and beliefs. (p. 46)

- **Saturno:** sexto planeta más cercano al Sol, también el segundo más grande; tiene el sistema de anillos más complejo. (p. 234)
- **ley científica:** enunciado acerca de lo que ocurre en la naturaleza, lo cual parece ser cierto en todo momento, sin explicar cómo o por qué algo ocurre. (p. 12)
- **métodos científico:** conjunto organizado de procedimientos de investigación que puede incluir el planteamiento de un problema, formulación de una hipótesis, investigación y recopilación de información, comprobación de la hipótesis, análisis de datos y elaboración de conclusiones. (p. 7)
- **tornillo:** máquina simple que consiste de un plano inclinado envuelto en espiral alrededor de un poste cilíndrico. (p. 173)
- **brisa marina:** brisa refrescante que sopla del mar hacia la tierra durante la tarde. (p. 533)
- **segunda ley de movimiento:** establece que la aceleración de un objeto es en la misma dirección que la fuerza neta del objeto y que la aceleración es igual a la fuerza neta dividida por su masa. (p. 102)
- **segunda ley de la termodinámica:** establece que es imposible que el calor fluya de un objeto frío a uno caliente, a menos que se realice un trabajo. (p. 274)
- **transporte de sedimentos:** movimiento de materiales erosionados por el viento, agua o glaciares de un lugar a otro. (p. 654)
- **Sedna:** nombre no oficial para el objeto 2003 VB12, un planetoide distante con una órbita muy elíptica. (p. 237)
- **circuito en serie:** circuito en el cual la corriente eléctrica tiene una sola trayectoria para seguir. (p. 407)
- **zona de sombra:** "zona muerta" entre 105 y 140 grados del epicentro de un terremoto, donde nada es registrado sobre un sismograma. (p. 371)
- **volcán de escudo:** or capas de lava basáltica que fluyeron libremente a alta temperatura. (p. 377)
- **máquina simple:** máquina que realiza el trabajo con un solo movimiento: palanca, polea, rueda y eje, plano inclinado, tornillo y cuña. (p. 166)
- **reacción de un solo desplazamiento:** reacción química en la cual un elemento reemplaza a otro elemento en un compuesto. (p. 731)
- **fricción deslizante:** fuerza de fricción que se opone al movimiento de dos superficies que se deslizan entre sí. (p. 84)
- **sociedad:** grupo de personas que comparten valores y creencias similares. (p. 46)

soil/strong base suelo/base fuerte

- **soil:** mixture of weathered rock, decaying organic matter, water, and air that overlies bedrock and is capable of supporting plant life. (p. 650)
- **solar eclipse:** occurs during new moon, when the Moon passes directly between the Sun and Earth, casting a shadow on part of Earth. (p. 201)
- **solenoid:** a wire wrapped into a cylindrical coil. (p. 432)
- **solstice:** occurs twice a year in June and December when Earth's rotation axis is tilted directly toward the Sun or away from the Sun. (p. 195)
- **solubility:** maximum amount of a solute that can be dissolved in a given amount of solvent at a given temperature. (p. 759)
- **solute:** in a solution, the substance being dissolved. (p. 753)
- **solution:** homogeneous mixture that remains constantly and uniformly mixed and has particles that are so small they cannot be seen with a microscope. (pp. 556, 752)
- **solvent:** in a solution, the substance in which the solute is dissolved. (p. 753)
- **specific heat:** amount of thermal energy needed to raise the temperature of 1 kg of a material 1°C. (p. 257)
- **spectroscope:** device that disperses light into its component wavelengths, using a prism or diffraction grating. (p. 822)
- **speed:** distance an object travels per unit of time. (p. 71)
- **sphere:** three-dimensional, round object whose surface is the same distance from the center in all directions. (p. 186)
- **standing wave:** a wave pattern that forms when waves of equal wavelength and amplitude, but traveling in opposite directions, continuously interfere with each other; has points called nodes that do not move. (p. 308)
- **static electricity:** the accumulation of excess electric charge on an object. (p. 392)
- **static friction:** frictional force that prevents two surfaces from sliding past each other. (p. 84)
- **streak:** color of a mineral in powdered form; helps identify a mineral and can be observed by rubbing a mineral on a white porcelain tile. (p. 611)
- **strong acid:** any acid that dissociates almost completely in solution. (p. 771)
- **strong base:** any base that dissociates completely in solution. (p. 772)

- suelo: mezcla de rocas degradadas, materia orgánica en descomposición, agua y aire que yace sobre el lecho rocoso y que es capaz de soportar la vida vegetal. (p. 650)
- eclipse solar: ocurre durante la luna nueva, cuando la Luna pasa directamente entre Sol y la Tierra, proyectando una sombra sobre una parte de la Tierra. (p. 201)
- **solenoide:** cable envuelto en forma de bobina cilíndrica. (p. 432)
- **solsticio:** ocurre dos veces un año en junio y diciembre en que el eje de rotación de la tierra se inclina directamente hacia el sol o lejos del sol. (p. 195)
- **solubilidad:** máxima cantidad de soluto que puede ser disuelto en una cantidad dada de solvente a una temperatura determinada. (p. 759)
- **soluto:** en una solución, la sustancia que está disuelta. (p. 753)
- **solución:** mezcla homogénea que permanece constante y uniformemente mezclada y que tiene partículas tan pequeñas que no pueden ser vistas en un microscopio. (pp. 556, 752)
- **solvente:** en una solución, la sustancia en la cual se disuelve el soluto. (p. 753)
- **calor específico:** cantidad de energía térmica necesaria para aumentar un grado centígrado la temperatura de un kilogramo de material. (p. 257)
- **espectroscopio:** dispositivo que dispersa la luz en las longitudes de onda que la componen, utilizando un prisma o rejilla de difracción. (p. 822)
- **velocidad:** distancia que recorre un objeto por unidad de tiempo. (p. 71)
- **esfera:** objeto redondo tridimensional cuya superficie está a la misma distancia desde el centro hacia todas las direcciones. (p. 186)
- onda estacionaria: patrón de una onda que se forma cuando ondas con la misma longitud de onda y amplitud, pero que viajan en direcciones opuestas, interfieren continuamente entre sí; tiene puntos llamados nodos que no se mueven. (p. 308)
- **electricidad estática:** la acumulación del exceso de carga eléctrica en un objeto. (p. 392)
- **fricción estática:** fuerza que evita que dos superficies en contacto se deslicen una sobre otra. (p. 84)
- **veta:** color de un mineral en forma de polvo; ayuda a identificar un mineral y puede observarse al frotar un mineral sobre una losa de porcelana blanca. (p. 611)
- **ácido fuerte:** cualquier ácido que se disocie casi por completo en una solución. (p. 771)
- **base fuerte:** cualquier base que se disocie completamente en una solución. (p. 772)

#### strong force/third law of motion

- **strong force:** attractive force that acts between protons and neutrons in an atomic nucleus. (p. 878)
- **subduction:** occurs when lithospheric plates converge and the edge of one plate is forced downward beneath another; recycles old lithosphere. (p. 359)
- **substance:** element or compound that cannot be broken down into simpler components and maintain the properties of the original substance. (p. 552)
- **subtropical high:** persistent, relatively stationary, high-pressure system. (p. 525)
- **sunspots:** cool, darker areas of the Sun's photosphere. (p. 827)
- **supersaturated solution:** any solution that contains more solute than a saturated solution at the same temperature. (p. 762)
- **suspension:** heterogeneous mixture containing a liquid in which visible particles settle. (p. 558)
- **synthesis reaction:** chemical reaction in which two or more substances combine to form a different substance. (p. 731)

### fuerza de atracción/tercera ley de movimiento

- **fuerza de atracción:** fuerza de atracción que actúa entre protones y neutrones en un núcleo atómico. (p. 878)
- **subducción:** fenómeno que ocurre cuando las placas litosféricas convergen y el borde de una placa es forzado a pasar por debajo del otro; recicla la litosfera antigua. (p. 359)
- sustancia: elemento o compuesto que no se puede descomponer en componentes más simples y que mantiene las propiedades de la sustancia original. (p. 552)
- **alto subtropical:** sistema persistente de alta presión relativamente estacionario. (p. 525)
- **manchas solares:** áreas frías y más oscuras de la fotosfera solar. (p. 827)
- **solución sobresaturada:** cualquier solución que contenga más solutos que una solución saturada a la misma temperatura. (p. 762)
- **suspensión:** mezcla heterogénea que contiene un líquido en el cual las partículas visibles se sedimentan. (p. 558)
- **reacción síntesis:** reacción química en la cual se combinan dos o más sustancias para formar una sustancia diferente. (p. 731)



- **technology:** application of science to help people. (p. 13)
- **temperature:** measure of the average kinetic energy of all the particles in an object. (p. 255)
- **temperature inversion:** an increase of temperature with height, resulting in very stable air that resists the rising needed for cloud formation or dispersal of air pollution. (p. 519)
- **texture:** describes the size and arrangement of rock components and can help indicate how a rock formed. (p. 617)
- **theory:** explanation of things or events that is based on knowledge gained from many observations and investigations. (p. 12)
- **thermal energy:** sum of the kinetic and potential energy of the particles in an object; is transferred by conduction, convection, and radiation. (p. 256)
- **third law of motion:** states that when one object exerts a force on a second object, the second object exerts a force on the first object that is equal in strength and in the opposite direction. (p. 113)

- **tecnología:** aplicación de la ciencia en beneficio de la población. (p. 13)
- **temperatura:** medida de la energía cinética promedio de todas las partículas en un objeto. (p. 255)
- **inversión de temperatura:** incremento de la temperatura con la altura, resultando en aire muy estable que resiste la elevación necesaria para la formación de nubes o dispersión de la polución del aire. (p. 519)
- **textura:** patrón que describe el tamaño y disposición de los componentes rocosos y que puede ayudar a indicar cómo está formada la roca. (p. 617)
- **teoría:** explicación de las cosas o eventos que se basa en el conocimiento obtenido a partir de numerosas observaciones e investigaciones. (p. 12)
- **energía térmica:** suma de la energía cinética y potencial de las partículas en un objeto, la cual se transfiere por conducción, convección y radiación. (p. 256)
- **tercera ley de movimiento:** establece que cuando un objeto ejerce una fuerza sobre un segundo objeto, el segundo objeto ejerce una fuerza igual de fuerte sobre el primer objeto y en dirección opuesta. (p. 113)

tide/ultraviolet waves marea/ondas ultravioleta

- **tide:** rise and fall in Earth's sea level, caused by a giant wave formed by the gravitational pull of the Sun and Moon. (p. 199)
- **time zone:** 15°-wide area on Earth's surface in which the time is the same. (p. 190)
- **tracer:** radioactive isotope, such as iodine-131, that can be detected by the radiation it emits after it is absorbed by a living organism. (p. 804)
- **transceiver:** device that transmits one radio signal and receives another radio signal at the same time, allowing a cordless phone user to talk and listen at the same time. (p. 473)
- transform boundary: plate tectonic boundary that exists as a large fault, or crack, along which lithospheric plates move in a horizontal direction. (p. 360)
- **transformer:** device that uses electromagnetic induction to increase or decrease the voltage of an alternating current. (p. 443)
- **translucent:** material that transmits some light but not enough to see objects clearly through it. (p. 327)
- **transmutation:** process of changing one element to another through radioactive decay. (p. 792)
- **transparent:** material that transmits almost all the light striking it so that objects can be clearly seen through it. (p. 327)
- **transverse wave:** wave for which the matter in the medium moves back and forth at right angles to the direction the wave travels; has crests and troughs. (p. 290)
- **troposphere:** lowest layer of Earth's atmosphere where most weather occurs and temperature normally decreases with height. (p. 519)
- **trough:** the lowest points on a transverse wave. (p. 294)
- **turbine:** large wheel that rotates when pushed by steam, wind, or water and provides mechanical energy to a generator. (p. 440)
- **Tyndall effect:** scattering of a light beam as it passes through a colloid. (p. 557)

- marea: elevación y caída del nivel del mar en la Tierra, causadas por una ola gigante formada por la atracción gravitacional del Sol y de la Luna. (p. 199)
- **zona horaria:**área sobre la superficie terrestre de 15° de ancho en la que la hora es la misma. (p. 190)
- indicador radiactivo: isótopo radioactivo, tal como el yodo-131, que puede ser detectado por la radiación que emite después de ser absorbido por un organismo vivo. (p. 804)
- radio transmisor-receptor: dispositivo que transmite y recibe una señal de radio al mismo tiempo, permitiendo que un usuario de un teléfono inalámbrico pueda hablar y escuchar al mismo tiempo. (p. 473)
- **límite de transformación:** límite de la placa tectónica que existe como una gran falla o grieta, a lo largo del cual las placas litosféricas se mueven en dirección horizontal. (p. 360)
- **transformador:** dispositivo que usa inducción electromagnética para aumentar o disminuir el voltaje de una corriente alterna. (p. 443)
- **translúcido:** material que transmite alguna luz pero no la suficiente para ver claramente los objetos a través del mismo. (p. 327)
- **transmutación:** proceso de cambio de un elemento a otro mediante la descomposición radioactiva. (p. 792)
- **transparente:** material que transmite casi toda la luz, chocándola de tal manera que los objetos pueden ser claramente vistos a través del mismo. (p. 327)
- onda transversal: onda para la cual la materia en el medio se mueve hacia adelante y hacia atrás en ángulos rectos respecto a la dirección en que viaja la onda; ésta tiene cresta y depresiones. (p. 290)
- **troposfera:** capa más baja de la atmósfera terrestre donde ocurre la mayoría de los fenómenos climáticos y la temperatura disminuye normalmente con la altura. (p. 519)
- **depresión:** los puntos más bajos en una onda transversal. (p. 294)
- **turbina:** rueda grande que gira al ser impulsada por vapor, viento o agua y que suministra energía mecánica a un generador. (p. 440)
- **efecto Tyndall:** difusión de un rayo de luz al pasar a través de un coloide. (p. 557)

Ū

- **ultraviolet waves:** electromagnetic waves with wavelengths between about 400 billionths and 10 billionths of a meter. (p. 465)
- **ondas ultravioleta:** ondas electromagnéticas con longitudes de onda entre aproximadamente 10 y 400 billonésimas de metro. (p. 465)

#### unbalanced forces/weak acid

#### fuerzas desbalanceadas/ácido débil

**unbalanced forces:** forces that combine to produce a net force that is not equal to zero and cause the velocity of an object to change. (p. 82)

**unconformity:** gap in the rock record representing a period of erosion or non-deposition. (p. 671)

uniformitarianism: Hutton's concept that the laws of nature act today as they have in the past. (p. 670)

**unsaturated solution:** any solution that can dissolve more solute at a given temperature. (p. 671)

**Uranus:** seventh planet from the Sun; appears bluegreen because of atmospheric methane, and its axis of rotation is tilted on its side. (p. 235)

**fuerzas desbalanceadas:** fuerzas que se combinan para producir una fuerza neta diferente a cero y causan que cambie la velocidad de un objeto. (p. 82)

**discordancia:** brecha en el registro rocoso que representa un periodo de erosión o falta de deposición. (p. 671)

uniformitarianismo: concepto de Hutton respecto a que las leyes de la naturaleza que actúan hoy día son iguales a las del pasado. (p. 670)

**solución no saturada:** cualquier solución que puede disolver más solutos a una temperatura determinada. (p. 671)

**Urano:** séptimo planeta más cercano al Sol; tiene una apariencia verde-azul debido al metano atmosférico, y cuyo eje de rotación está inclinado hacia un lado. (p. 235)



variable: factor that can cause a change in the results of an experiment. (p. 9)

**vector:** a physical quantity that is specified by both a size and a direction. (p. 71)

**velocity:** the speed and direction of a moving object. (p. 73)

**Venus:** second planet outward from the Sun; has a dense, atmosphere of mostly carbon dioxide and very high surface temperatures. (p. 224)

viscosity: a fluid's resistance to flow. (p. 375)

**visible light:** electromagnetic waves with wavelengths of 750 to 400 billionths of a meter that can be detected by human eyes. (p. 465)

**voltage difference:** related to the force that causes electric charges to flow; measured in volts (V). (p. 400)

**volume:** amount of space occupied by an object. (p. 18)

variable: factor que puede causar un cambio en los resultados de un experimento. (p. 9)

**vector:** cantidad física que está especificada por un tamaño y una dirección. (p. 71)

**velocidad direccional:** la rapidez y dirección de un objeto en movimiento. (p. 73)

**Venus:** segundo planeta más cercano al Sol; tiene una atmósfera densa compuesta principalmente de dióxido de carbono y una temperatura superficial muy alta. (p. 224)

viscosidad: resistencia de un fluido al flujo. (p. 375)

**luz visible:** ondas electromagnéticas con longitudes de onda entre 400 y 750 billonésimas de metro y que pueden ser detectadas por el ojo humano. (p. 465)

diferencia de voltaje: se refiere a la fuerza que causa que las cargas eléctricas fluyan; se mide en voltios (V). (p. 400)

**volumen:** espacio ocupado por un objeto. (p. 18)

W

water table: boundary separating the saturated zone from the unsaturated zone. (p. 664)

wave: a repeating disturbance or movement that transfers energy through matter or space. (p. 288)

wavelength: distance between one point on a wave and the nearest point just like it. (p. 295)

weak acid: any acid that only partly dissociates in solution. (p. 771)

**tabla de agua:** límite que separa la zona saturada de la zona insaturada. (p. 664)

**onda:** alteración o movimiento repetitivo que transfiere energía a través de la materia o el espacio. (p. 288)

**longitud de onda:** distancia entre un punto en una onda y el punto semejante más cercano. (p. 295)

**ácido débil:** cualquier ácido que solamente se disocie parcialmente en una solución. (p. 771)

weak base/X rays base débil/rayos X

- weak base: any base that does not dissociate completely in solution. (p. 772)
- weather fronts: zones in which air masses interact. (p. 526)
- weathering: process of physical or chemical breakdown of materials at or near Earth's surface, influenced by factors such as the nature of the parent material, climate, and time. (p. 646)
- wedge: simple machine that is an inclined plane with one or two sloping sides. (p. 173)
- weight: gravitational force exerted on an object. (p. 106)
- westerlies: global winds that blow from the west in the middle latitudes. (p. 524)
- wheel and axle: simple machine that consists of a shaft or axle attached to the center of a larger wheel, so that the shaft and the wheel rotate together. (p. 171)
- white dwarf: giant star that has lost its outer layers, leaving behind a hot, dense core that continues to contract under gravity. (p. 825)
- work: transfer of energy that occurs when a force makes an object move; measured in joules. (p. 154)

- **base débil:** cualquier base que no se disocie completamente en una solución. (p. 772)
- **frentes climáticos:** zonas en las que interactúan las masas de aire. (p. 526)
- **desgaste:** proceso de fraccionamiento físico o químico de materiales en o cerca de la superficie terrestre, influenciado por factores como la naturaleza del material de origen, el clima y el tiempo. (p. 646)
- **cuña:** máquina simple que consiste de un plano inclinado con uno o dos lados en declive. (p. 173)
- **peso:** fuerza gravitacional ejercida sobre un objeto. (p. 106)
- vientos del oeste: vientos globales que soplan desde el oeste en las latitudes medias. (p. 524)
- **rueda y eje:** máquina simple que consiste de una barra o eje sujeto al centro de una rueda de mayor tamaño de manera que el eje y la rueda giran juntos. (p. 171)
- **enana blanca:** estrella gigante que ha perdido sus capas externas, dejando un núcleo denso y caliente que continúa contrayéndose bajo la gravedad. (p. 825)
- **trabajo:** transferencia de energía que se produce cuando una fuerza hace mover un objeto y que se mide en julios. (p. 154)

X

- **X rays:** electromagnetic waves with wavelengths between about 10 billionths of a meter and 10 trillionths of a meter, that are often used for medical imaging. (p. 467)
- rayos X: ondas electromagnéticas con longitudes de onda entre 10 billonésimas de metro y 10 trillonésimas de metro, las cuales se utilizan con frecuencia para producir imágenes de uso médico. (p. 467)

Absolute dating Air

Italic numbers = illustration/photo Bold numbers = vocabulary term lab = a page on which the entry is used in a lab act = a page on which the entry is used in an activity

A

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#### **ONLINE STUDY TOOLS**

- Section Review Quizzes
- Math Practice
- Interactive Tutor
- Vocabulary PuzzleMaker
- Chapter Review Tests
- Standardized Test Practice
- Concepts in Motion
- BrainPOP Movies
- Multilingual Glossary
- Vocabulary eflashcards

#### ONLINE RESEARCH

- WebQuest Projects
- Frescreened Web Links
- Unit Projects
- Internet Labs

#### ONLINE STUDENT EDITION

Complete Student Edition available at mhin.com

#### **FOR TEACHERS**

Teaching Today—Professional Development

SAFETY SYMBOLS	HAZARD	EXAMPLES	PRECAUTION	REMEDY	
DISPOSAL	Special disposal procedures need to be followed.	certain chemicals, living organisms	Do not dispose of these materials in the sink or trash can.	Dispose of wastes as directed by your teacher.	
BIOLOGICAL	Organisms or other biological materials that might be harmful to humans	bacteria, fungi, blood, unpreserved tissues, plant materials	Avoid skin contact with these materials. Wear mask or gloves.	Notify your teacher if you suspect contact with material. Wash hands thoroughly.	
EXTREME TEMPERATURE	Objects that can burn skin by being too cold or too hot	boiling liquids, hot plates, dry ice, liquid nitrogen	Use proper protection when handling.	Go to your teacher for first aid.	
SHARP OBJECT	Use of tools or glass- ware that can easily puncture or slice skin	razor blades, pins, scalpels, pointed tools, dissecting probes, bro- ken glass	Practice common- sense behavior and follow guidelines for use of the tool.	Go to your teacher for first aid.	
FUME C	Possible danger to respiratory tract from fumes	ammonia, acetone, nail polish remover, heated sulfur, moth balls	Make sure there is good ventilation. Never smell fumes directly. Wear a mask.	Leave foul area and notify your teacher immediately.	
ELECTRICAL	Possible danger from electrical shock or burn	improper grounding, liquid spills, short circuits, exposed wires	Double-check setup with teacher. Check condition of wires and apparatus.	Do not attempt to fix electrical problems. Notify your teacher immediately.	
IRRITANT	Substances that can irritate the skin or mucous membranes of the respiratory tract	pollen, moth balls, steel wool, fiberglass, potassium perman- ganate	Wear dust mask and gloves. Practice extra care when handling these materials.	Go to your teacher for first aid.	
CHEMICAL	Chemicals can react with and destroy tissue and other materials	bleaches such as hydrogen peroxide; acids such as sulfuric acid, hydrochloric acid; bases such as ammo- nia, sodium hydroxide	Wear goggles, gloves, and an apron.	Immediately flush the affected area with water and notify your teacher.	
тохіс	Substance may be poisonous if touched, inhaled, or swallowed.	mercury, many metal compounds, iodine, poinsettia plant parts	Follow your teacher's instructions.	Always wash hands thoroughly after use. Go to your teacher for first aid.	
FLAMMABLE (8)	Flammable chemicals may be ignited by open flame, spark, or exposed heat.	alcohol, kerosene, potassium perman- ganate	Avoid open flames and heat when using flammable chemicals.	Notify your teacher immediately. Use fire safety equipment if applicable.	
OPEN FLAME	Open flame in use, may cause fire.	hair, clothing, paper, synthetic materials	Tie back hair and loose clothing. Follow teacher's instruction on lighting and extinguish- ing flames.	Notify your teacher immediately. Use fire safety equipment if applicable.	



## **Eye Safety**

Proper eye protection should be worn at all times by anyone performing or observing science activities.



# Clothing

Protection
This symbol appears when substances could stain or burn clothing.



## **Animal Safety**

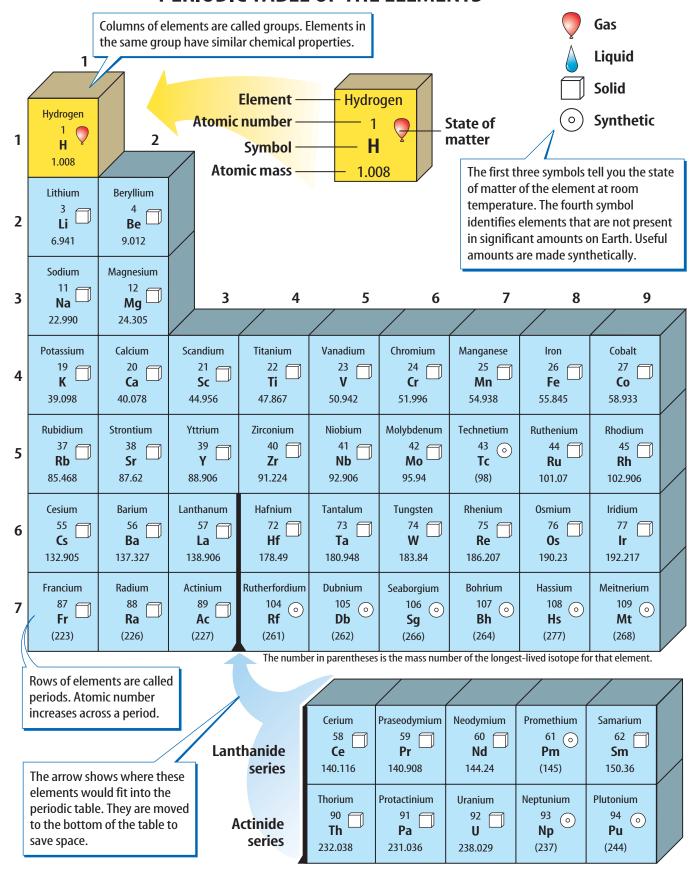
This symbol appears when safety of animals and students must be ensured.

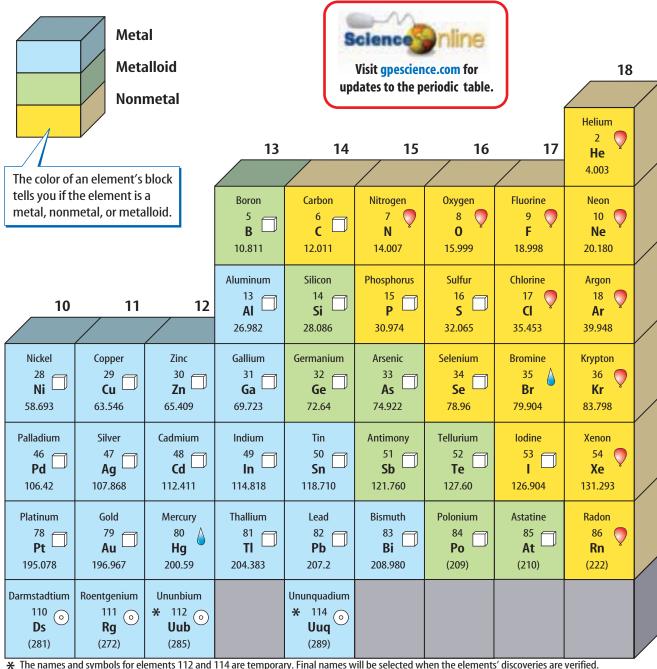


## Handwashing

After the lab, wash hands with soap and water before removing goggles.

## PERIODIC TABLE OF THE ELEMENTS





\* The names and symbols for elements 112 and 114 are temporary. Final names will be selected when the elements' discoveries are verified.

Europium 63 Eu 151.964	Gadolinium 64 <b>Gd</b> 157.25	Terbium  65 <b>Tb</b> 158.925	Dysprosium  66  Dy  162.500	Holmium 67 <b>Ho</b> 164.930	Erbium  68  Er  167.259	Thulium  69 <b>Tm</b> 168.934	Ytterbium 70 <b>Yb</b> 173.04	Lutetium 71 Lu 174.967	
Americium 95 Am (243)	Curium 96	Berkelium 97	Californium 98	Einsteinium 99	Fermium 100	Mendelevium 101 o Md (258)	Nobelium 102 (o) <b>No</b> (259)	Lawrencium 103  Lr (262)	